DOCUMENT RESUME

ED 225 013 CE 034 966

TITLE	Environmental Support Specialist, Blocks III & IV, 17-5. Military Curriculum Materials for Vocational and Technical Education.
INSTITUTION	Air Force Training Command, Sheppard AFB, Tex.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
PUB DATE	78
NOTE	487p.; For related documents see CE 034 965-968.
PUB TYPE	Guides - Classroom Use - Materials (For Learner) (051) -- Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF02/PC20 Plus Postage.
DESCRIPTORS	Chemical Analysis; *Chemical Reactions; *Environmental Technicians; Guidelines; Laboratory Manuals; Lesson Plans; Military Personnel; Military Training; Postsecondary Education; *Quality Control; Sanitation; *Technical Education; Water; *Water Quality; *Water Treatment; Workbooks
IDENTIFIERS	Military Curriculum Project

ABSTRACT

This military-developed text contains the second section of a four-part course to train environmental support specialists. Covered in the individual course blocks are operative principles of water treatment plants (principles of water treatment plants, the clarification process, water systems filters, chemical disinfection, taste and odor control, color control, fluoridation and defluoridation, water distribution systems, and internal corrosion and scale) and specialized water treatment (ion exchangers and controls, electrodialysis demineralization, specialized water treatment, distillation, and field water purification). This section contains both teacher and student materials. Printed instructor materials include lesson plans with an outline of teaching steps and a plan of instruction detailing the units of instruction, the duration of the lesson, objectives, and supportive materials needed. Among the student materials provided are two study guides containing objectives, assignments, text readings, and review questions; two workbooks containing exercises and lab work; and a manual on servicing ion exchangers. (MN)

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MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

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Military Curriculum Materials
WRITE OR CALL
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
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The Ohio State University · 1960 Kenny Road · Columbus, Ohio 43210
Tel (614) 486-3655 Cable: CTVOCEDOSU/Columbus, Ohio

Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

ENVIRONMENTAL SUPPORT SPECIALIST, BLOCKS III & IV

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Developed by:

United States Air Force

Development and Review Dates:

September 25, 1975

D.O.T. No.:

168.168

Occupational Area:

Public Service

Target Audiences:

Grades 13-adult

Print Pages:

457

Cost:

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:	Type of Materials: Lesson Plans:	Type of Materials: Programmed Text:	Type of Materials: Student Workbook:	Type of Materials: Handouts:	Type of Materials: Text Materials:	Type of Materials: Audio-Visuals:	Instructional Design: Performance Objectives:	Instructional Design: Tests:	Instructional Design: Review Exercises:	Instructional Design: Additional Materials Required:	Type of Instruction: Group Instruction:	Type of Instruction: Individualized:
			No. of pages									
Block III — *Operative Principles of Water Treatment Plants*	●		27		●	★	●		●	★	●	
Block IV — *Specialized Water Treatment*	●		22		●	★	●		●	★	●	

★ Materials are recommended but not provided.

Expires July 1, 1978

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Course Description:

This is the second section of a four-part course to train environmental support specialists. The entire course includes training in water treatment plants, operating procedures for solid waste disposal, and maintenance of water and waste processing system components. The previous section dealt with waste processing and water analysis. This section discusses the operative principles of water treatment plants and specialized water treatment. It consists of two blocks covering 154 hours of instruction.

Block III — *Operative Principles of Water Treatment Plants* contains eight lessons covering 78 hours of instruction. The lesson topics and respective hours follow:

Principles of Water Treatment Plants (8 hours)
Clarification Process (24 hours)
Water Systems Filter and Field Trip (16 hours)
Chemical Disinfection (5.5 hours)
Taste, Odor, and Color Control (2.5 hours)
Fluoridation and Defluoridation (2.5 hours)
Water Distribution Systems (5.5 hours)
Internal Corrosion and Scale (14 hours)

Block IV — *Specialized Water Treatment* has five lessons covering 76 hours of instruction.

Ion Exchangers and Controls (32 hours)
Electrodialysis Demineralization (5.5 hours)
Specialized Water Treatment (2.5 hours)
Distillation (16 hours)
Field Water Purification Unit (20 hours)

This section contains both teacher and student materials. Printed instructor materials include lesson plans with an outline of teaching steps and a plan of instruction detailing the units of instruction, the duration of the lesson, objectives, and support materials needed. Student materials include two study guides containing objectives, assignments, text readings, and review questions; two workbooks containing exercises and lab work; and a manual on servicing ion exchangers.

Several military technical manuals and commercially produced texts were also referenced but not provided. Audiovisuals recommended for the entire four sections but not provided include twenty films, three slide sets, and one schematic diagram. This section should be preceded by **Environmental Support Specialist, Blocks I and II** (17-4) and followed by **Environmental Support Specialist, Blocks V-VII** (17-6). It can be presented in a large group instructional setting or adapted for individualized study in waste treatment or ecology courses.

17-5

PLAN OF INSTRUCTION	COURSE TITLE Environmental Support Specialist

BLOCK TITLE

Operating Principles of Water Treatment Plants

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
1. Principles of Water Treatment Plants	8 (6/2) Day 16	**Column 1 Reference** / **STS Reference**
a. Identify components of a water system by matching numbered units of schematics of water systems with names of the units.	(4.5/1.5)	1a 7f(1), 7f(2), 7f(5), 7f(10), 7g(6), 7k 1b 7e(1)(a), 7e(1)(c), 7e(1)(d), 7e(3), 7e(6) 7e(7), 7e(8), 7f(1), 7f(5), 7f(10), 7k **Instructional Materials** SG 3ABR56330-III-1, Principles of Water Treatment Plants WB 3ABR56330-III-1-P1, Principles of Water Treatment Plants
b. Given a list of components of a water system and a list of phrases or statements relating to the function of equipment, match the name of the components to the related phrase or statement.	(1.5/0.5)	AFM 85-13, Maintenance and Operation of Water Plants and Systems **Training Equipment** Trainer, Water Treatment System (12) **Training Methods** Discussion (4.5 hrs) Demonstration (0.5 hr) Performance (1 hr) Outside Assignment (2 hrs) **Instructional Environment/Design** Classroom (4.5 hrs) Laboratory (1.5 hrs) Study Hall (2 hrs) Group/Lockstep **Instructional Guidance** Discuss the relationship between required components of a water system and the sources, need for treatment, and type of distribution system.

11 15 4

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		Review the characteristics of impurities in water. Discuss the general methods and equipment used to treat water and use trainer to identify basic equipment used. Direct students to read study guide III-1 and answer the questions on pages 8 and 9 for outside assignment.
2. Clarification Process	24 (18/6) Days 17, 18 and 19	Column 1 Reference STS Reference 2a 7e(1)(a), 7e(2), 7e(6), 7e(7), 7f(8), 7f(9), 7f(10) 2b 7a, 7e(1)(a), 7e(2), 7e(6), 7e(7)
a. Define terms and answer questions relative to water clarification, softening and stabilization by completing applicable measurable written items.	(9/3)	Instructional Materials SG 3ABR56330-III-2, Clarification of Water WB 3ABR56330-III-2-P1, Clarification of Water WB 3ABR56330-III-2-P2, Operating a Water Treatment Plant
b. Following instructions provided by the instructor, as a team member, operate the water treatment trainer to remove turbidity and hardness, and to stabilize the water.	(9/3)	Audio Visual Aids TVS 56-4, Clarification of Water Training Equipment Trainer, Water Treatment System (12) Training Methods Discussion (8 hrs) Demonstration (3 hrs) Performance (7 hrs) Outside Assignment (6 hrs) Instructional Environment/Design Classroom (8 hrs) Laboratory (10 hrs) Study Hall (6 hrs) Group/Lockstep

PLAN OF INSTRUCTION NO. 3ABR56330	DATE 6 June 1975	BLOCK NO. III	PAGE NO. 16

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PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2
3. **Water Systems Filters and Field Trip**	16 (12/4) Days 20 and 21
a. Using AFM 85-13 and TO 40W4-9-1, identify components of a rapid sand filter and a diatomaceous earth filter by matching the name of the components to pictured components and, from recall, complete incomplete written statements relative to operation of filters.	(4/1.5)
b. Following instructions, backwash and place the filter on the water treatment system trainer in service.	(2/0.5)
c. Following field trip to municipal water treatment plant and using notes or recall, list major components of the plant, list chemicals used and their purpose, and write answers to questions relative to plant operation.	(6/2)

SUPPORT MATERIALS AND GUIDANCE 3

Instructional Guidance

Discuss the principles and methods of clarification, softening and stabilization. Show film and have students complete WB 3ABR56330-III-2-P1. Demonstrate procedures for mixing chemicals and operating equipment. Stress safety during demonstration. Provide information needed on chemical dosages and have class operate the trainer.

On day 17, have students read pages 10 thru 16 of SG III-2. On day 18, assign students to read pages 17 thru 22 of SG III-2. On day 19, direct students to read pages 23 thru 29 of SG III-2 and answer the questions on pages 29 and 30.

Column 1 Reference	STS Reference
3a	7e(1)(a), 7e(3), 7e(4), 7e(5), 7f(10), 8a, 8d, 8e
3b	7e(1)(a), 7f(4), 7f(10)
3c	7e(6), 7e(7), 7e(8), 7f(1), 7f(3), 7f(4), 7f(5), 7f(6), 7f(7), 7f(10), 7f(12), 7f(13)

Instructional Materials

SG 3ABR56330-III-3, Water System Filters
WB 3ABR56330-III-3-P1, Identification of Rapid Sand Filter Components
WB 3ABR45330-III-3-P2, Identification of Diatomaceous Earth Filter Components
WB 3ABR45330-III-3-P3, Field Trip to Municipal Water Treatment Plant
AFM 85-13, Maintenance and Operation of Water Treatment Plants and System
TO 40W4-9-1 Water Purification Unit

Audio Visual Aids

FLC 3-62, Clean, Clear Water
MN 7489B, Water Purification
TVS 56-1, Water Plant Operation

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		Training Equipment Trainer, Water Treatment System (12) Erdlator D. E. Filter (12) **Training Methods** Discussion (2.5 hrs) Demonstration (1.5 hrs) Performance (3.5 hrs) Field Trip (4.5 hrs) Outside Assignment (4 hrs) **Instructional Environment/Design** Classroom (2.5 hrs) Laboratory (5 hrs) Field Trip (4.5 hrs) Study Hall (4 hrs) Group/Lockstep **Instructional Guidance** Day 20: Discuss filters and filter operation, show film on filter operations, identify components of filters and demonstrate backwash of filters. Have each student backwash filter while others are completing workbooks. On day 20, have students read pages 31 thru 51 of SG III-3. Day 21: Conduct field trip to municipal water treatment plant explaining equipment, chemicals, and safety. On return to classroom show films for review and have students complete workbooks. On day 21, direct students to review pages 31 thru 51 of SG III-3 and answer the questions on pages 51 and 52 for outside assignment.

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
4. Chemical Disinfection	5.5 (4/1.5) Day 22	**Column 1 Reference** / **STS Reference** 4a — 7e(8), 7f(6), 7f(13), 9h 4b — 7e(8), 7f(5) **Instructional Materials** SG 3ABR56330-III-4, Methods of Disinfection and Purification WB 3ABR56330-III-4-P1, Water Disinfection and Purification **Training Equipment** Hypochlorinators (6) **Training Methods** Discussion (1.5 hrs) Demonstration (0.5 hrs) Performance (2 hrs) Outside Assignment (1.5 hrs) **Instructional Environment/Design** Classroom (1.5 hrs) Laboratory (2.5 hrs) Study Hall (1.5 hrs) Group/Lockstep **Instructional Guidance** Discuss principles and terms of chlorination, equipment used and safety. Discuss and demonstrate mathematics of computing dosages and feed rates. Have students compute dosages and feed rates and adjust feeders. Have students read pages 53 thru 74 of SG III-4 and answer the questions on pages 74 and 75 for outside assignment.
a. Define terms, answer questions and determine dosages relative to disinfection of water by writing response to measurable written items.	(1.5/0.5)	
b. Given flow rate, dosage, concentration of solution, and required formulas, compute rate hypochlorinator must feed solution and as a member of a team, adjust hypochlorinator to feed determined amount to ± 10 ml per minute.	(2.5/1)	

PLAN OF INSTRUCTION NO.	DATE	BLOCK NO.	PAGE NO.
3ABR56330	6 June 1975	III	19

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
5. Taste, Odor, and Color Control	2.5 (2/0.5) Day 22	Column 1 Reference — STS Reference 5a — 7e(1)(b), 7e(1)(c), 7e(1)(d), 7e(3), 7e(6) 5b — 7e(1)(b), 7e(1)(c), 7e(1)(d), 7e(3), 7e(6)
a. Demonstrate knowledge relative to cause of, control of, and treatment for taste, odor, and color by writing responses to measurable written items.	(1/0.3)	Instructional Materials SG 3ABR56330-III-6, Taste, Odor, and Color Control WB 3ABR56330-III-5-P1, Taste, Odor, and Color Control
b. Using prepared samples, chemicals, and jar test equipment, and following written instructions, as a team, treat water for taste, odor, color, iron, manganese, and algae.	(1/0.2)	Training Equipment Jar Test Equipment (12) Training Methods Discussion (1 hr) Performance (1 hr) Outside Assignment (0.5 hr) Instructional Environment/Design Classroom (1 hr) Laboratory (1 hr) Study Hall (0.5 hr) Group/Lockstep Instructional Guidance Discuss principles of taste, odor, and color removal. Provide samples, chemicals, and equipment. Provide guidance to student performance and emphasize safety in handling chemicals. Direct students to read pages 77 thru 81 of SG III-5 and answer the questions on page 81 for outside assignment.

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
6. Fluoridation and Defluoridation	2.5 (2/0.5) Day 23	Column 1 Reference: 6a, 6b STS Reference: 7f(7)
a. Demonstrate knowledge of principles of fluoridation and defluoridation by writing responses to measurable written items.	(1/0.2)	Instructional Materials SG 3ABR56330-III-6, Fluoridation and Defluoridation of Water WB 3ABR56330-III-6-P1, Fluoridation and Defluoridation of Water
b. Given flow rate of water, determine fluoride dosage, concentration of solution, and solution feed rate needed to provide 1 ppm fluorides, and as a member of a team, adjust feeder to deliver required feed.	(1/0.3)	Training Equipment Chemical Feeders (6) Training Methods Discussion (1 hr) Performance (1 hr) Outside Assignment (0.5 hr) Instructional Environment/Design Classroom (1 hr) Laboratory (1 hr) Study Hall (0.5 hr) Group/Lockstep Instructional Guidance Discuss principles of fluoridation and defluoridation, review computations required and have students complete objectives. Have students read pages 82 thru 88 of SG III-6 and answer questions on pages 88 and 89 for outside assignment.
7. Water Distribution Systems	5.5 (4/1.5) Day 23	Column 1 Reference: 7a, 7b STS Reference: 7f(4), 7g(6), 7h, 7j, 7k
a. Answer questions relative to function and operation of components of a water distribution system by writing response to measurable written items.	(2.5/1)	

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
b. Using AFM 85-13 and a line drawing showing numbered symbols for pipes and valves, identify type and/or position of valves, size of pipes, and names of components.	(1.5/0.5)	Training Materials SG 3ABR56330-III-7, Water Distribution Systems WB 3ABR56330-III-7-P1, Water Distribution Systems AFM 85-13, Maintenance and Operation of Water Plants and Systems Training Methods Discussion (2.5 hrs) Performance (1.5 hrs) Outside Assignment (1.5 hrs) Instructional Environment/Design Classroom (2.5 hrs) Laboratory (1.5 hrs) Study Hall (1.5 hrs) Group/Lockstep Instructional Guidance Discuss function and operation of components of distribution systems and monitor/check student's performance. Direct students to read pages 90 thru 94 of SG III-7 and answer questions on page 94 for outside assignment.
8. Internal Corrosion and Scale	14 (10/4) Days 24 and 25	Column 1 Reference — STS Reference 8a — 7e(6) 8b — 7e(2), 7e(6), 7f(12), 11h(7)
a. Demonstrate a knowledge of internal scale and corrosion and the causes and treatment for, by matching terms or items of information with related phrases or statements.	(6/2)	Instructional Materials SG 3ABR56330-III-8, Internal Corrosion and Scale WB 3ABR56330-III-8-P1, Internal Corrosion and Scale Automatic pH Control Operating Manual

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PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
b. Following written instructions as a class team member, operate the pH controller trainer to adjust water to a pH of 10 ± .5 pH unit.	(4/2)	Training Equipment Automatic pH Controller Trainer (12) Training Methods Discussion (5 hrs) Demonstration (1 hr) Performance (4 hrs) Outside Assignments (4 hrs) Instructional Environment/Design Classroom (5 hrs) Laboratory (5 hrs) Study Hall (4 hrs) Group/Lockstep Instructional Guidance Discuss water using systems, causes of scale and corrosion and methods of controlling them. Demonstrate/discuss operation of trainer and monitor student's performance. Make outside assignments and check each daily: Day 24, read SG III-8; On day 24, have students read pages 95 thru 100 of SG III-8 and answer questions on pages 100 and 101; For day 25, direct students to review SGs III-1 thru III-8 to prepare for block measurement test.
9. Measurement Test and Test Critique	(2/0) Day 25	

PLAN OF INSTRUCTION	COURSE TITLE **Environmental Support Specialist**
BLOCK TITLE **Specialized Water Treatment**	

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
1. Ion Exchangers and Controls	**32 (24/8) Days 26, 27 28, and 29**	**Column 1 Reference** **1a, 1b, 1c, 1d** **STS Reference** **7f(11)(a), 7f(13)** **Instructional Materials** **SG 3ABR56330-IV-1, Ion Exchangers** **WB 3ABR56330-IV-1-P1, Operation of Water Softener Trainer** **563X0 Career Ladder, Servicing of Ion Exchangers** **AFM 85-13, Maintenance and Operation of Water Plants and Systems** **Audio Visual Aids** **SAFB 169, Role of the Ion Exchanger** **TVS 56-7a, Ion Exchanger** **Training Equipment** **Sodium Cation Exchanger (6)** **Hydrogen Cation Exchanger (6)** **Mixed Bed Demineralizer (12)** **Water Softener Trainer (12)** **Dual Bed Demineralizer (12)** **Training Methods** **Discussion (8 hrs)** **Demonstration (4 hrs)** **Performance (12 hrs)** **Outside Assignments (8 hrs)**
a. Using an ion exchanger unit, trace the water flow through the unit for each cycle of operation.	**(6/2)**	
b. Using an ion exchanger unit, adjust the controls to direct water flow through the unit for each cycle of operation.	**(6/2)**	
c. Using a dual or mixed bed demineralizer, observing safety precautions, and working as a team, regenerate the unit and place in service.	**(6/2)**	
d. Using the written instructions in part H, section 13, AFM 85-13, inspect the ion exchanger units and perform the required maintenance.	**(6/2)**	

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
		Instructional Environment/Design Classroom (8 hrs) Laboratory (16 hrs) Study Hall (8 hrs) Group/Lockstep **Instructional Guidance** Demonstrate the operating procedure for each of the ion exchangers. Emphasize safety in handling chemicals. Let each student operate one of the cation exchangers. As a team they may regenerate the dual bed and the mixed bed demineralizers. Make and check outside assignments daily: Day 26, pages 1-10 in SG IV-1 thru 5; Day 27, pages 10-20 in SG IV-1 thru 5, and answer questions on pages 19 and 20; Day 28, review pages 1 thru 20 in SG IV-1 thru 5; Day 29, review figures 2 and 4 in SG IV-1 thru 5.
2. Electrodialysis Demineralization	5.5 (4/1.5) Day 30	**Column 1 Reference** 2a, 2b **STS Reference** 7f(11)(b), 7f(13)
a. Following written instructions, inspect, start, and stop the electrodialysis unit.	(1.5/0.5)	**Instructional Materials** SG 3ABR56330-IV-2, Electrodialysis Demineralization WB 3ABR56330-IV-2-P1, Operation and Maintenance of the Electrodialysis Demineralizer
b. Following written instructions and working as a team, assemble a repeated section of a membrane stack.	(2.5/1)	**Training Methods** Discussion (1.5 hrs) Demonstration (0.5 hr) Performance (2 hrs) Outside Assignment (1.5 hrs)

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION HOURS 2	SUPPORT MATERIALS AND GUIDANCE 3
		Instructional Environment/Design Classroom (1.5 hrs) Laboratory (2.5 hrs) Study Hall (1.5 hrs) Group/Lockstep **Instructional Guidance** Before operating or repairing the equipment, discuss electrical hazards and stress careful handling of membranes.
3. Specialized Water Treatment	**2.5 (2/0.5) Day 30**	**Column 1 Reference** 3a **STS Reference** 7f(11)(c)
a. Using related information, state the application of the reverse osmosis process of water treatment.	(2/0.5)	**Instructional Materials** SG 3ABR56330-IV-3, Specialized Water Treatment WB 3ABR56330-IV-3-P1, Specialized Water Treatment **Training Methods** Discussion (1.5 hrs) Performance (0.5 hr) Outside Assignment (0.5 hr) **Instructional Environment/Design** Classroom (1.5 hrs) Laboratory (0.5 hr) Study Hall (0.5 hr) Group/Lockstep **Instructional Guidance** Discuss principles of reverse osmosis for treating water. Also, briefly discuss new developments in water treatment. Make and check outside assignments daily: Pages 21-42 in SG IV-1 thru 5 and answer questions on pages 38 and 42.

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION HOURS 2	SUPPORT MATERIALS AND GUIDANCE 3
4. Distillation	16 (12/4) Days 31 and 32	**Column 1 Reference** / **STS Reference** 4a 9a, 9b 4b 9c, 9d 4c 9e, 9f, 9g, 9h, 9i
a. Using related information, state the need for conversion of saline water and methods of distillation.	(1/0)	**Instructional Materials** SG 3ABR56330-IV-4, Distillation of Water WB 3ABR56330-IV-4-P1, Distillation Terms WB 3ABR56330-IV-4-P2, Operating the Meco Water Distillation Unit WB 3ABR56330-IV-4-P3, Flow Pattern for Vapor Compression Distillation Units
b. Following written instructions and working as a team, operate the distillation equipment to produce salt free water.	(5/2)	**Audio Visual Aids** TVS 56-5a, Distillation MN 7489c, Water Purification, Vapor Compression Distillation
c. Following written and oral instructions and working as a team, inspect, clean, and perform required maintenance of distillation units.	(6/2)	**Training Equipment** Meco Vapor Compression Distillation Trainer (12) **Training Methods** Discussion (5 hrs) Demonstration (2 hrs) Performance (5 hrs) Outside Assignments (4 hrs) **Instructional Environment/Design** Classroom (5 hrs) Laboratory (7 hrs) Study Hall (4 hrs) Group/Lockstep **Instructional Guidance** Stress safety when handling the units and when handling chemicals. Locate the components and give their function on the trainer. Let each student operate the trainer in the starting and stopping procedures. Assignment; Day 31, answer questions on pages 56 and 57 in SG IV-1 thru 5. Day 32, answer questions on pages 72 and 73.

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
5. Field Water Purification Unit	20 (16/4) Days 33, 34 and 35	Column 1 Reference STS Reference 5a 8a 5b 8b 5c 8c, 8d 5d 8c, 8e, 8f Instructional Materials SG 3ABR56330-IV-5, Field Water Treatment Equipment (Erdlator) WB 3ABR56330-IV-5-P1, Operation of Field Water Treatment Equipment TO 40W4-9-1, Water Purification Unit Audio Visual Aids TVS 56-3, Set-up, Operation, and Maintenance on the 600 GPH Portable Water Purification Unit Training Equipment Water Purification Unit, 600 GPH, Portable Trailer Mounted (12) Training Methods Discussion (5 hrs) Demonstration (1 hr) Performance (10 hrs) Outside Assignments (4 hrs) Instructional Environment/Design Classroom (5 hrs) Laboratory (11 hrs) Study Hall (4 hrs) Group/Lockstep
a. Using related information, state the purpose and application of the field water purification unit.	(1/0)	
b. Following procedures in TO 40W4-9-1, working as a team, perform a preoperational inspection and service of the field water purification unit.	(5/2)	
c. Following procedures in TO 40W4-9-1, working as a team, operate the field water purification unit.	(6/2)	
d. Following procedure outlined in TO 40W4-9-1, clean the water purification unit and position the valves to allow precoat of the DE filter.	(4/0)	

PLAN OF INSTRUCTION NO. 3ABR56330	DATE 6 June 1975	BLOCK NO. IV	PAGE NO. 28

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		Instructional Guidance Allow students, as a group, to inspect, apply chemicals, and operate the field water purification unit. The performance will consist of each student operating the pressure filter in the filter and backwash positions. Make and check outside assignments daily: On day 33 direct students to read pages 74 thru 79 in SG IV-1 thru 5. On day 34, have the students answer questions on page 80 in SG and review pages 1 thru 80 in SG IV-1 thru 5.
6. Related Training (as shown in course chart)	2	
7. Measurement Test and Test Critique	(2/0) Day 35	

PLAN OF INSTRUCTION NO 3ABR56330	DATE 6 June 1975	BLOCK NO. IV	PAGE NO. 29

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/17Jun75 Jenkins	INSTRUCTOR
COURSE NUMBER 3ABR56630	COURSE TITLE Environmental Support Specialist
BLOCK NUMBER III	BLOCK TITLE Operating Principles of Water Treatment Plants

LESSON TITLE
Principles of Water Treatment Plants (Day 16)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
6 Hrs	2 Hrs	8 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
15	6 June 1975	1

STS/CTS REFERENCE

NUMBER	DATE
STS 566X0	28 July 1971

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Water Treatment System	None	None	SG III-1 WB III-1-P1 AFM 85-13

CRITERION OBJECTIVES AND TEACHING STEPS

1a. Identify components of a water system by matching numbered units of schematics of water systems with names of the units.

(1) Water supply sources and components

(2) Water treatment components

(3) Distribution systems and components

1b. Given a list of components of a water system and a list of phrases or statements relating to the function of equipment, match the name of the components to the related phrase or statement.

(1) Characteristics of and impurities in raw water supplies

(2) Physical treatment processes and equipment

(3) Chemical treatment processes and equipment

Course No: 3ABR56330 Branch Approval: Bobby Littlejohn
Day 16 Date: 3 Feb 75

PART II

INTRODUCTION (30 Min)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (300 Min)

PRESENTATION:

1a. Identify components of a water system by matching numbered units of schematics of water systems with names of the units.

(1) Water supply sources and components

(a) Water supply requirements

(b) Sources of water supply

1 Surface

a Lakes

b Rivers

2 Ground

a Wells

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b Springs

3 Other

a Sea water

b Snow

c Rainfall

(c) Components of water supply system

1 Natural lakes

2 Dams and impounding reservoirs

3 Holding reservoirs

4 Surface water pipes

5 **Wells**

6 **Well pumps**

(2) **Water treatment components**

a) Need for water treatment
remove impurities and modify
characteristics to provide
potable water for domestic and
industrial use which is:

1 Clear

2 Free of taste and odor

3 Free of disease producing
organisms

- Stable in respect to scale
and corrosion

basic water treatment unit

s

1 Clarification units

2 Disinfection units

(3) Distribution systems and components

(a) Requirements of a distribution system

(b) Ground storage or clear well

(c) High lift pumps

(d) Elevated storage

(e) Pneumatic tanks and components

(f) Distribution lines

1 Mains

2 Laterals

(g) Valves

1b. Given a list of components of a water system and a list of phrases or statements relating to the function of equipment, match the name of the components to the related phrase or statement.

(1) Characteristics of and impurities in raw water supplies

(a) Characteristics of the compound water

1 Chemical composition H_2O

2 Physical state-liquid at normal temperature and pressure; freezing point 0° C-boiling 100°C

3 Density-for practical purposes, density is 1 gram per cc or ml; 8.34 lbs per gal.

4 Ionization constant of water is 1x10-14

5 Tasteless, odorless, and colorless.

6 Universal solvent

(b) Characteristics due to impurities in raw water supplies

1 Turbidity-muddy or unclear condition due to suspended solids

2 Color

a True color mostly due to dissolved or colloidal organic vegetable dyes from decaying vegetation-may be due to Fe, Mn, or industrial waste.

b Apparent color due to suspended solids

3 Hardness-a characteristic of water which causes excess soap consumption and scale formation in pipes and equipment

4 Corrosiveness- tendency to corrode metals due to low pH or dissolved gases

5 pH is the measure of free hydrogen ion concentration in water.

6 Temperature-may affect use or treatment

7 Taste and odor due to dissolved organic matter or dissolved gases

8 Acidity-strong base neutralising capacity usually due to excess CO_2 but maybe due to H_2S or H_2SO_4 from mine drainage

9 Alkalinity-strong acid neutralising capacity. In natural waters it is usually caused by HCO_3 and to a lesser extent by CO_3

10 Contaminated-contains disease producing organisms or toxic materials

(c) Impurities in raw water supplies

1 Gases

a Oxygen-some dissolved O_2 is desirable for domestic supplies but will cause corrosion if in excess b CO_2-the form which CO_2 takes in water depends on the type and amount of minerals in the water and the pH of water

CO_2 reacts with (OH) alkalinity in water to form CO_3. At a pH above 9.5, CO_2 will be in CO_3 form

CO_2 reacts with the CO_3 in water to form HCO_3. At pH 8.3, all CO_2 will be in the HCO_3 form. Below pH of 8.3, additional CO_2 will form H_2CO_3. At a pH 4.8, all CO_2 will be H_2CO_3 or free CO_2.

The acidity of most natural water supplies is due to the free CO_2 and is more common to well waters

The alkalinity of most water supplies is due to the HCO_3 and minor amounts of CO_3

c Hydrogen sulfide-H_2S is normally found in ground waters with high sulfate content.

Causes taste-odor problem (rotten egg odor)

Reacts with O_2 to form H_2SO_4 which causes corrosion of metals and concrete.

d Some dissolved organic taste and odor causing compounds may produce vapors or liquid which will vaporize if water is aerated

2 Liquids-not usually present

3 Solids

a Total solids-any residue left after evaporation and drying b Suspended solids-solids which can be removed by a filter includes:

Settleable solids such as rocks, sand, silts, and some organic materials which will settle out under still conditions.

Non-settleable solids-finely suspended solids such as clay and colloidal particles which can be filtered out but will not settle under normal conditions.

c Dissolved solids (inorganic) due to the solubility of minerals in the earth with which water comes in contact. Natural water supplies usually contain varying amounts of the following ions and/or their associated compounds:

Sodium (Na^+)-Most sodium compounds are very soluble in water. Anions which cannot be associated with Ca, Fe, Mg, or Mn are usually considered to be sodium salts. They contribute to the overall saltiness or brackishness of a water supply.

Calcium (Ca++) and Magnesium (Mg++) cause most of the hardness in water. Soap reacts with Ca or Mg ions to form a curdy precipitate

Calcium carbonate is only slightly soluble in cold water (15 ppm)

Calcium bicarbonate is soluble in cold water but may break down, especially when heated, to form $CaCO_3$ or CO_2

Calcium sulfate is soluble in water but may scale out on hot metal surfaces, or precipitate with $CaCO_3$, or will precipitate if $SO_4 =$ content is high

Calcium chloride is very soluble in water

Magnesium (Mg++)-$MgSO_4$ and $MgCL_2$ are soluble in water

Magnesium hydroxide is very insoluble in water and is not present in raw water; but, the carbonates and bicarbonates may decompose to precipitate the Mg as $Mg(OH)_2$

Iron and manganese-due to insolubility as hydroxides, the Fe^{++} or Mn^{++} are only slightly soluble (7 ppm) in water and then only if sufficient CO_2 is present to lower the pH. If oxidised to a higher state (Fe^{++} or Mn^{++}), they are insoluble except at extremely low pH not normally found in natural water supplies.

Although present in small amounts only, they are troublesome because they cause taste, odor and apparent color.

Carbonates (CO_3)-most carbonates are soluble except $CaCO_3$, which forms part of the alkalinity of water and breakdown at high temperature to form CO_2. Changed to bicarbonates by lowering pH.

Bicarbonates-all bicarbonates are soluble. At pH 8.3, all CO_2 is in bicarbonate form; bicarbonates are the alkalinity of natural waters.

Bicarbonates are converted to free CO_2 by lowering the pH. Bicarbonates breakdown when heated to form CO_2 and CO_3.

Sulfates (SO_4)- most sulfates are soluble except $CaSO_4$. At high concentrations in drinking water, they have a laxative effect (limited to 250 PPM in potable water). Under anaerobic conditions, SO_4 will be broken down to H_2S causing taste, odor, and corrosion problems.

Chlorides (CL-)- most chlorides are soluble in water. They impart a salty taste. Potable water should not have over 250 ppm of NaCl.

Silica-silica is present in small amounts in most water supplies in the form of Na_4SiO_4 or as colloidal SiO_2. It is not normally a problem except where it forms a hard glassy scale at high temperatures or combines with other scale to bind and make it hard.

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Fluorides (F-)- when found in water in excess, fluorides causes mottling of teeth (fluorosis) and must be removed. Where absent, they are added to prevent tooth decay in young people.

Other-presence of other minerals in water in sufficient concentrations to be objectionable are usually due to pollution and may require special treatment.

EPA identifies most of these materials and sets the limit to the concentration allowable

4 Biological composition

a Pathogenic organisms (disease producing)

Bacteria-which cause typhoid fever, dysentery, cholera

Viruses-which cause hepatitis

Amoeba-which cause amoebic dysentery

b Nuisance organisms- organisms which may not cause disease but cause taste, odor, color, clogging of equipment.

Algae

Fungi

Blood worms

c Indicator organisms- organisms which may have no direct effect on use of water but their presence indicates pollution and presence of pathogenic organisms

(2) Physical treatment processes and equipment

(a) Processes

1 Sedimentation-used to remove settleable suspended solids

2 Aeration

a Removes dissolved gases such as CO_2 and H_2S

b May allow some organic taste and odor compounds to vaporize

c Adds O_2 to water to oxidize Fe or Mn

3 Filtration-Strains or filters suspended solids.

4 Flocculation-Keeps solids suspended and brings them in contact with coagulated particles to allow growth of particles.

5 Distillation

6 Reverse osmosis

(b) Equipment for physical processes

1 Holding reservoirs for plain sedimentation

2 Aerators

  a Tower

  b Spray

  c Diffused air

3 Flocculators

4 Sedimentation tanks

  a Horizontal flow-rectangular or circular design

  b Up flow

(3) Chemical treatment processes and equipment

- (a) Chemical processes
  - 1 Chemical oxidation
    - a Oxidize Fe and Mn
    - b Oxidize taste and odor
  - 2 Chemical precipitation
    - a Coagulation
    - b Fe and Mn removal
    - c Softening
  - 3 Stabilization
  - 4 Disinfection

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5 Algae control

6 Ion exchange

7 Activated carbon

(b) Equipment for chemical treatment processes

1 Chemical feeders

  a Gas feeders

  b Solution feeders

  c Dry feeders

  d Slurry feeders

2 Chemical mixers

3 Contact tanks

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APPLICATION:

Using AFM 85-13, notes, and study guide, students will complete WB III-1-P1, Principles of Water Treatment Plants

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (30 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

1. Review SG 3ABR56330-III-1 and answer questions

   Read SG 3ABR56330-III-2 pages 10 thru 13

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/17Jun75	INSTRUCTOR
COURSE NUMBER 3ABR56330	COURSE TITLE Environmental Support Specialist
BLOCK NUMBER III	BLOCK TITLE Operating Principles of Water Treatment Plants

LESSON TITLE
Clarification Process (Days 17, 18, and 19)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
18 Hrs	6 Hrs	24 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
16	6 June 1975	2

STS/CTS REFERENCE

NUMBER	DATE
STS 563X0	28 July 1971

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Water Treatment System	None	None	SG III-2 WB III-2-P1 WB III-2-P2 TVS 56-4

CRITERION OBJECTIVES AND TEACHING STEPS

2a. Define terms and answer questions relative to water clarification, softening, and stabilization by completing applicable measurable written items.

(1) Clarification of water
(2) Water softening
(3) Stabilization for scale and corrosion control
(4) Clarification and softening equipment

2b. Following instructions provided by the instructor, as a team member, operate the water treatment trainer to remove turbidity and hardness, and to stabilize the water.

(1) Identification and function of unit components

ATC FORM AUG 72 770

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(2) Chemical requirements

(3) Operation of chemical feeders

(4) Operational procedures and safety

Course No: 3ABR56330
Days 17, 18, and 19

Branch Approval: Bobby Littlejohn
Date: 3 Jul 75

PART II

INTRODUCTION (30 Min)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (1020 Min)

2a. Define terms and answer questions relative to water clarification, softening, and stabilization by completing applicable measurable written items.

(1) Clarification of water

(a) Definition-the removal of turbidity (suspended solids) during clarification. Other goals such as color removal, taste, and odor and removal of most organisms may be accomplished as complementary treatment or side effects to the clarification process.

(b) Methods of clarification

1 Plain sedimentation in streams, lakes, or holding reservoirs

2 Filtration alone where turbidity is very low

3 Coagulation and flocculation followed by sedimentation and filtration

(c) Principles of coagulation and flocculation

1 Definitions

a Coagulation is the precipitation of certain ions or compounds to form colloidal particles which will combine with other colloidal particles to form larger hydrous jelly-like particles called floc

b Flocculation-the growth of the smaller particles into larger particles

2 Coagulant materials

a Coagulants-aluminum sulfate $Al_2(SO_4)2$ (ALUM), ferrous sulfate $FeSO_4$ (Copperas), ferric sulfate $Fe_2(SO_4)$, ferric chloride $FeCl_3$

b Sources of alkalinity-natural alkalinity in water, lime (CaO or $Ca(OH)_2$), crushed limestone ($CaCO_3$), soda ash (Na_2CO_3)

c Coagulant aids-chlorine (used to oxidize ferrous iron or to activate silica), activated silica, organic polymers.

3 Chemical reactions

a Basic reactions-ions of heavy metals plus alkalinity forms a hydrated jellylike precipitate.
EXAMPLE:
$Fe^{+++}CL_3^{-} + 3H^{+} + (OH^{-})$
Yields $Fe(OH)_3 + 3HCl$
NOTE: The result of this reaction tends to lower the pH and if natural alkalinity is not adequate, alkaline material must be added

b Alkalinity reactions-sources of $(OH)^-$ such as $NaHCO_3$ yields Na^+ $(OH)^-$ + CO_2. This reaction will go to the right as the coagulant removes the (OH) in the water. $CaO + H_2O$ yields $Ca + 2\ (OH)$

c Reaction with different coagulants -$Al_2(SO_4)_3$ + $6NaHCO_3$ yields $Al(OH)_3$ + 6Na + $3(SO_4)$ + 6 CO_2

$FeCl_3$ + 3NaHCO yields Fe $(OH)_3$ + 3Na + 3Cl + $3CO_2$

$Fe_2(SO_4)_3$- same as Al_2SO_4

$Fe(SO_4)$-before the Fe will coagulate it must be oxidized to Fe+++ by aeration or chlorination

2Fe+++ +Cl_2 yields 2FE+++ + Cl the reactions would then be the same for $FeCl_3$

d Coagulation reaction- although the basic precipitation is as shown above, one molecule of the $Fe(OH)_3$ can link with others

$Fe(OH)_3$ + Fe $(OH)_3$ yields HOH + FeOFe $(OH)_4$ to form larger particles

e Flocculation reaction- coagulated particles usually carry a (+) residual charge. Colloidal clay particles usually carry a (-) residual charge.

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Stirring the water brings the coagulated particles and clay particles in contact which allows them to adhere to each other and grow into larger particles called floc.

4 Factors affecting coagulation and flocculation

- a Type and concentration of colloidal material in raw water
- b Type and dosage of coagulant
- c Optimum pH
- d Temperature of water
- e Time and degree of agitation

5 Jar test-multiple test to determine proper coagulant and pH range. Daily test for daily variations

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(2) Water softening

(a) Types of hardness

1 Temporary hardness

$CaCO_3$-least soluble

$Ca(HCO_3)_2$

$MgCO_3$

$Mg(HCO_3)_2$

$Ca(OH)_2$-in treated water only

2 Permanent hardness

$CaSO_4$

$CaCl_2$

$MgSO_4$

$MgCl_2$

(b) Alkalinity in raw water

1 Causes of alkalinity

a (OH-)

b CO_3

c HCO_3

2 Types of alkalinity (as measured)

a "P"

b "M"

3 Relationship of "P" and "M" alkalinity to amount of (OH) CO_3 and HCO_3

a If $P = 0$, all alkalinity (M) is (HCO_3)

b If $P = M$, all alkalinity (M) is (OH)

c If $P = \frac{1}{2}M$, all alkalinity (M) is (CO_3)

d If P is greater than $\frac{1}{2}M$, $(OH) = 2P - M$ and $CO_3 = 2(M-P)$

e If P is less than $\frac{1}{2}M$, $CO_3 = 2P$ and $HCO_3 = M - 2P$

(c) Methods of water softening

1 Chemical precipitation (Lime-soda)

a "Ca" temporary hardness- $Ca(HCO_3)_2 + Ca\ (OH)_2$ yields $CaCO_3 + H_2O$

b "Ca" permanent hardness-
$Mg(HCO_3)_2 + Ca(OH)_2$
yields $CaCO_3 + 2NaCl$

c "Mg" temporary hardness-
$Mg(HCO_3)_2 + Ca(OH)_2$ yields
$Mg(OH)_2 + 2CaCO_3 + 2H_2O$

d "Mg" temporary hardness-
$MgCl_2 + Ca(OH)_2 + Na_2CO_3$
yields $Mg(OH)_2 + CaCO_3 + 2NaCl$

e Addition of coagulant may be necessary to aid in settling

CONCLUSION (DAY 17)

SUMMARY:

STUDY ASSIGNMENT:

Read SG 3ABR56330-III-2, Clarification of Water

INTRODUCTION (DAY 18)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

2a. Continued:

(3) Stabilization for scale and corrosion control

(a) Definition

1 Recarbonation is used to precipitate excess lime as $CaCO_3$ which is then removed by sedimentation. This is followed by additional CO_2 to adjust pH to change remaining $CaCO_3$ to soluble $Ca(HCO_3)2$. Note: Excess CO_2 would cause corrosion.

2 Use of polyphosphates

a Prevents Ca and Mg from forming scale (sequestering)

b Prevents corrosion by forming a protective film on pipes(a corrosion inhibitor)

3 Aeration to remove excess CO_2 to prevent corrosion

4 pH adjustment with acids or alkalies- not normally used for distribution systems

(c) Determining stability of water with relation to $CaCO_3$

1 Factors affecting stability

- a ppm Ca as $CaCO_3$- to scale; to corrosion
- b ppm alkalinity-to scale; to corrosion
- c pH (increasing)-to scale; to corrosion
- d Temperature (increasing)- to scale; to corrosion
- e Total solids- to scale; to corrosion

2 Test for determining stability

- a Langelier index—based on above factors and chart b Marble test-measures pH and alkalinity of water saturated with $CaCO_3$

c Stability test-determines difference in alkalinity before and after saturation with $CaCO_3$. If alkalinity is greater after saturation water may be corrosive. If alkalinity is less after saturation water may cause scale

(4) Clarification and softening equipment

(a) Plain sedimentation reservoirs

(b) Filter-for clarification before or after precipitation, coagulation and flocculation(will be covered later in course)

(c) Chemical feeders

1 Solution feeders

2 Dry feeders

3 Lime slakers

4 Slurry feeders

5 Gas feeders

(d) Horizontal sedimentation clarifiers or softeners.

1 Rapid mixers

2 Slow mixers

3 Settling tanks

(e) Upflow sludge blanket clarifiers-softeners.

1 Erdlators

2 Clarifiers

3 Accelator

(f) Spiractor (softener)

(g) Recarbonators

(h) Filters

CONCLUSION (DAY 18)

SUMMARY:

STUDY ASSIGNMENT:

Review SG 3ABR56330-III-2, Clarification of Water and answer questions.

INTRODUCTION (DAY 19)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

OVERVIEW.

MOTIVATION:

PRESENTATION:

2b. Following instructions provided by the instructor, as a team member, operate the water treatment trainer to remove turbidity and hardness, and to stabilize the water.

(1) Identification and function of unit components

(a) Raw water supply tank

(b) Aerator

1 Remove CO_2 (corrosion control)

2 Removes taste and odor.

3 Adds O_2-aids coagulation if iron salts used. Oxidizes Fe and Mn.

(c) Chemical feeders.

(d) Rapid mixer

(e) Filter

(f) Flocculation

(g) Recarbonator

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(h) Sedimentation tank

(i) Clear well

(j) Storage reservoir

(k) Valves, controls, and pumps

(2) Chemical requirements

(a) Based on flow and analysis of water

(b) Chemical requirements for softening

(c) Chemicals required for stabilization

(d) Safety precautions for handling chemicals

(3) Operation of chemical feeders

(a) Solution feeders

- 1 Principles of operation
- 2 Lubrication requirements
- 3 Screen and poppet check
- 4 Feed adjustments

(b) Slurry feeder

- 1 Feed control
- 2 Agitator

(c) Recarbonation

- 1 Pressure control
- 2 Diffuser

(4) Operational procedures and safety

(a) Equipment check

(b) Check electrical control switches

(c) Filling tanks and adjusting flow control

(d) Starting mixers, chemical feeders, and pumps

(e) Operation of sludge collectors

(f) Checking quality of treated water

(g) Removing equipment from service

APPLICATION:

Students will complete objective 2a by completing WB III-2-P1

Students will complete objective 2b by operating the water treatment trainer as a team member.

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during the lesson. This may be accomplished at any time during lesson to increase effectiveness.

CONCLUSION (30 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

Read SG 3ABR56330-III-3, Water Systems Filters.

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/17Jun75	INSTRUCTOR
COURSE NUMBER 3ABR56330	COURSE TITLE Environmental Support Specialist
BLOCK NUMBER III	BLOCK TITLE Operating Principles of Water Treatment Plants

LESSON TITLE
Water Systems Filters and Field Trip (Days 20 and 21)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
12 Hrs	4 Hrs	16 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
17	6 June 1975	3

STS/CTS REFERENCE

NUMBER	DATE
STS 563X0	28 July 1971

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Water Treatment System Erdlator D.E. Filter	None	None	SG III-3 WB III-3-P1 WB III-3-P2 WB III-3-P3 AFM 85-13 TO 40W4-9-1 FLC 3-62 MN 7489B TVS 56-1

CRITERION OBJECTIVES AND TEACHING STEPS

3a. Using AFM 85-13 and TO 40W4-9-1, identify components of a rapid sand filter and a diatomaceousearth filter by matching the name of the components to pictured components and, from recall, complete incomplete written statements relative to operation of filters.

(1) Types of filters

(2) Diatomaceous earth filtration

(3) Components of diatomaceous earth filter

(4) Components of rapid sand filters

(5) Operation of rapid sand filters

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

3b. Following instructions, backwash and place the filter on the water treatment system trainer in service.

(1) Operational procedures

(2) Applicable safety

3c. Following field trip to municipal water treatment plant and using notes or recall list major components of the plant, list chemicals used and their purpose, and write answers to questions relative to plant operation.

(1) Safety as applicable

(2) Treatment processes

(3) Identification of equipment

(4) Plant operation data

Course No: 3ABR56330
Days 20 and 21

Branch Approval: Billy Littlejohn
Date: 3 Jul 75

PART II

INTRODUCTION (20 Min)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

ATTENTION:

MOTIVATION:

BODY (680 Min)

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PRESENTATION:

3a. Using AFM 85-13 and TO 40W4-9-1, identify components of a rapid sand filter and a diatomaceous earth filter by matching the name of the components to pictured components and, from recall, complete incomplete written statements relative to operation of filters.

(1) Types of filters

(a) According to filter media

1 Sand

2 Diatomaceous earth

3 Anthrafilt

4 Fiber

5 Activated carbon (absorbent rather than physical)

(b) According to types of feed

1 Gravity

2 Pressure

3 Vacuum (seldom used)

(c) According to flow rate

1 Slow (seldom used)

2 Rapid

3 Roughing (seldom used)

5

(d) Specific types of filters commonly used for water clarification

  1 Rapid sand filters

    a Gravity rapid sand filters

    b Pressure rapid sand filters

  2 Pressure diatomaceous earth filters

(2) Diatomaceous earth filtration

  (a) Diatomaceous earth

  (b) General operation of D.E. filter

  (c) Advantages of D.E. filtration

(3) Components of diatomaceous earth filter

- (a) Filter elements
- (b) Filter shell
- (c) Slurry tank
- (d) Air relief valve
- (e) Rate of flow controller
- (f) Control valves
- (g) Pressure gages

(4) Components of rapid sand filters

(b) Hydrants are connected to main feeder line. Normally located on streets 400 ft. apart, so that every building can be reached from 2 hydrants with not more than 300 feet of hoses

1 Standard type for normal street use

2 Flush type or pit mounted for airfield apron use

(5) Prevention of back siphonage (Back flow)

(a) Back siphonage is the backing up of contaminated or polluted water into the potable water system.

(b) Back siphonage conditions frequently occur because of carelessness of users.

(c) Prevent back siphonage by

1 Elimination of connection
2 Separation by air gap
3 Back flow preventer
4 Testing and maintenance

(6) Water hammer control

(a) Water hammer is a rapid pressure fluctuation above and below the line pressure in a closed system caused by rapid closing of valves.

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1 Internal combustion engine cooling systems

2 Hot water heating systems

3 Refrigeration chilled water systems

(4) Scale and corrosion control in open recirculation systems (cooling towers)

(a) Factors affecting scale and corrosion in cooling towers

1 Concentration of solids due to loss of water by evaporation

2 Saturation of water with dissolved oxygen

3 Possible high temperatures

4 Algae and bacterial growth in tower and lines

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5 Electro-chemical corrosion of different metals

(b) Methods of control

1 Softening of make-up water

2 Blow down to limit concentration of solids

3 pH adjustment to prevent $CaCO_3$ precipitation

4 Polyphosphates to keep Ca and Mg in solution and as a corrosion inhibitor

5 Chlorination or other chemicals to control biological growths

(5) Scale and corrosion control in closed recirculation systems

(a) Since a minimum of make up water is used, scale is little problem

2 Air binding

3 Channeling

4 Algae and bacterial growths

5 Incrustation (lime and iron deposits)

3b. Following instructions, backwash and place the filter on the water treatment system trainer in service.

(1) Operational procedures

(a) Filling the filter

(b) Operation of clear well pump

(c) Flow through filter

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(d) Backwash procedures

(e) Shut down procedures

(2) Applicable safety

(a) Electrical hazards

(b) Improper adjustment of valves

CONCLUSION (Day 20)

SUMMARY:

STUDY ASSIGNMENT:

Review SG 3ABR56330-III-3, Water Systems
Filters, and answer questions.

INTRODUCTION (Day 21)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

3c. Following field trip to municipal water treatment plant and using notes or recall, list major components of the plant, list chemicals used and their purpose, and write answers to questions relative to plant operation.

(1) Safety as applicable

  (a) Keep hands off equipment on field trip

  (b) Do not handle chemicals

  (c) Stay behind rails

  (d) Stay with group

(2) Treatment processes

  (a) Taste and odor control

  (b) Clarification

  (c) Softening

(d) Stabilization

(e) Fluoridation

(f) Disinfection

(3) Identification of equipment

(a) Chemical feeders

1 Gravimetric loss of weight feeders for lime and soda ash

2 Lime slakers

3 Volumetric solution feeders (dipper type) for coagulation

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4 Chlorinators

5 Ammoniators

6 Diaphram type solution
feeders for silica, phosphates,
and fluorides

7 Slurry pumps for activated
carbon

(b) Measuring devices-rapid mix

(c) Slow mix or flocculators

(d) Filters

(e) Wash water recovery well and
reservoir

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(f) Sedimentation basins

(g) Accelator

(h) Lab facilities

(4) Plant operation data

(a) Plant capacity

(b) Backwash data

1 When to backwash

2 Amount of water used

3 Time required

APPLICATION:

1. Complete WB 3ABR56330-III-3-P1 and P2, and complete incomplete statements. (objective 3a)

2. Each student will backwash the filter and place it in service (objective 3b)

3. Complete WB 3ABR56330-III-3-P3 (objective 3c)

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson to increase effectiveness.

CONCLUSION (20 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

1. Read SG 3ABR56330-III-4, Methods of Disinfection and Purification, and answer questions.

2. Read SG 3ABR56330-III-5, Taste, Odor, and Color control, and answer questions.

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/17Jun75	INSTRUCTOR
COURSE NUMBER 3ABR56330	COURSE TITLE Environmental Support Specialist
BLOCK NUMBER III	BLOCK TITLE Operating Principles of Water Treatment Plants
LESSON TITLE Chemical Disinfection (Day 22)	

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
4 Hrs	1.5 Hrs	5.5 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
19	6 June 1975	4

STS/CTS REFERENCE

NUMBER	DATE
STS 563X0	28 July 1971

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Hypochlorinators	None	None	SG III-4 WB III-4-P1

CRITERION OBJECTIVES AND TEACHING STEPS

4a. Define terms, answer questions, and determine dosages relative to disinfection of water by writing response to measurable written items.

(1) Meaning of and requirements for disinfection

(2) Methods of disinfection

(3) Forms of chlorine used

(4) Terms and chemical reactions relative to chlorination

(5) Factors affecting the efficiency of chlorination

(6) Computing chlorine dosage
(7) Chemical feeders used for chlorination
(8) Safety relative to chlorination

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

4b. Given flow rate, dosage, concentration of solution, and required formulas, compute rate hypochlorinator must feed solution and as a member of a team, adjust hypochlorinator to feed determined amount to ± 10 ml per minute.

(1) Information needed to determine feeder flow rate

(2) Formulas used to determine hypochlorinator setting

(3) Procedures for adjusting hypochlorinator

Course No: 3ABR56330
Day 22

Branch Approval: Bobby Littlejohn
Date: 3 Jul 75

PART II

INTRODUCTION (10 Min)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (210 Min)

PRESENTATION:

4a. Define terms, answer questions, and determine dosages relative to disinfection of water by writing response to measurable written items.

(1) Meaning of and requirements for disinfection

(a) Disinfection-process of killing pathogenic bacteria

(b) Sterilization-process of killing all living organisms

(c) Pathogenic organisms-disease producing

1 Bacterial diseases

a Typhoid

b Dysentery (bacillary)

c Cholera

2 Virus diseases (suspected)

a Infectious hepatitis

b Polio

3 Protozoan diseases

a Amoebic dysentery

b Schistosomiasis

(d) Coliform-bacteria which are not normally pathogenic, but their presence indicates contamination by feces of warm-blooded animals

(2) Methods of disinfection

(a) Boiling

(b) Ozone(O_3)

(c) Ultra violet rays

(d) Halazone or iodine

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(e) Lime

(f) Potassium permanganate

(g) Silver

(h) Chlorination(most common method of disinfection)

(3) Forms of chlorine used

(a) Chlorine gas (liquid under pressure)

(b) $Ca(OCl)_2$ -Calcium hypochlorite (HTH)

(c) Na(OCl) -Sodium hypochlorite (household bleach is about a 5% solution)

(d) ClO_2 -Chlorine dioxide (a gas produced by adding Cl_2 to sodium chlorite on site. It is seldom used.

(4) Terms and chemical reactions relative to chlorination

(a) Reactions

1 $Cl_2 + H_2O$ yields $HCl + HOCl$

2 $HOCl$ yields $H + OCl^-$
This is a reversible
reaction which is pH
dependent.

3 $Ca(OCl)_2 + H_2O$ yields
$Ca(OH)_2 + 2HOCl$

4 $NaOCl + H_2O$ yields
$Na(OH) + HOCl$

5 $NH_3 + HOCl$ yields NH_2Cl
or $NHCl_2$ (chloramines)

6 Additional HOCl will destroy
the chloramines to produce
nitrogen gases

7 Some organic materials are
oxidized to CO_2

8 Some organic materials may
combine with chlorine to
form chlorinated compounds
which can cause taste and odors

9 $Fe^{++} + Cl_2$ yields $Fe^{+++} Cl^-$

10 $H_2S + Cl_2$ yields $S + 2HCl$

11 HOCl and the chloramines are the disinfecting agents

  a HOCl is the most effective

  b Chloramines require high residuals and long contact time

(b) Terms relative to disinfection

1 Total chlorine residual- the chlorine in the water in form of HOCl and OCl or chloramines

2 Free available chlorine- the HOCl and OCl

3 Combined available chlorine-the chloramines

4 Chlorine demand-the amount of chlorine required to react with oxidizable materials in the water

5 Chlorine dosage(requirements)-the amount of chlorine required to meet the demand and provide the required Cl residual

6 Marginal chlorination- the chlorination of water to a specified residual with no consideration to how much is free available or combined available

7 Break point chlorination-the addition of sufficient chlorine to oxidize the chloramines and leave only a free available Cl residual.

8 Chlorine-ammonia treatment-the addition of ammonia and chlorine following break point chlorination to form combined Cl residual

9 Superchlorination-addition of excess chlorine which is then removed by sulphur dioxide, aeration, or activated carbon

(5) Factors affecting the efficiency of chlorination

(a) Chlorine demand (ppm)

(b) Required residual

(c) Demand + residual = dosage

(6) Computing chlorine dosage

(a) Dosage in ppm

(b) Quantity of water (millions of gallons)

(c) 8.34 (factors to convert gallons to lbs)

(d) % available chlorine in compound

(c) **Formula:**
MG(decimal value) x 8.34 x ppm (dosage) x % Chlorine (decimal value) = lbs chemical required

(7) Chemical feeders used for chlorination

(a) Chlorinators (gas feeders)

1 Direct feed-feed gas directly to non pressurised flow. Used only in emergency

2 Vacuum type solution feeders-gas is drawn into a high pressure stream by an ejector (aspirator) and then fed to stream

a Water seal diaphram (bell jar)

b Mechanical diaphram

(b) Hypochlorinators-chemical feeders which feed a solution of $Ca(OCl)_2$ or Na OCl directly to water being treated

(c) Types of chemical feeders according to method or degree of control

1 Manual control-operator must stop/start

2 Semi automatic-starts/stops with flow

3 Automatic-keeps feed rate proportional to flow rate
NOTE: The feed rate must be set by operator for all types

(8) Safety relative to chlorination

(a) Characteristics of chlorine which makes it hazardous:

1 Chlorine gas is a respiratory irritant and at higher concentratio can be fatal

2 It is a strong oxidizing agent

a Very corrosive in presence of moisture

b Can support combustion with some organic materials

3 It is a pressurized gas and the pressure will increase with increase in temperature

4 Chlorine ice crystals are formed by too rapid withdrawal of Cl_2 from cylinder, or by Cl_2 being below 49.2°c in combination with H_2O at a 1% solution. Ice crystals cause improper operation of chlorinator.

5 The gas is heavier than air and can settle in low places

(b) Safety precautions in handling chlorine gas

1 Allow only qualified personnel to handle chlorine and equipment

2 Provide proper gas mask and train personnel in its use.

3 Do not apply direct heat to chlorine containers or equipment. Keep out of direct sunlight

4 Keep equipment dry

5 Repair all leaks as soon as detected. Note: Leaks may be detected with ammonia water

6 Do not store combustible materials in chlorine rooms

7 Keep chlorinator room warm and do not withdraw Cl_2 at a rate of over 40 lbs per day from 150 lb cylinders or 400 lbs per day from 1 ton tank to prevent icing.

8 Provide exhaust fans to discharge from floor level to outside

(c) Hazards of $Ca(OCl)_2$ and Na OCl

1 Ca $(OCl)_2$ deteriorates to produce chlorine monoxide and oxygen

2 At high temperature it can cause fire in presence of organic material

3 In presence of moisture or organic material it can cause spontaneous combustion

4 Chlorine solutions are corrosive

(d) Safety practices relative to using Ca $(OCl)_2$

1 Store in cool dry environment

2 Avoid breathing fumes

3 Do not store with combustible materials or with equipment that corrodes

4 Hypochlorites should be handled in corrosive resistant materials

5 Use safety equipment such as rubber gloves and aprons when handling bulk amounts of hypochlorites.

4b. Given flow rate, dosage, concentration of solution, and required formulas, compute rate hypochlorinator must feed solution and as a member of a team, adjust hypochlorinator to feed determined amount to ± 10 ml per minute.

(1) Information needed to determine feeder flow rate

(a) Flow rate of water (Ml per min)
NOTE: Gal. x 3785 = ml

(b) Concentration of solution (ppm)
NOTE: (ml solution ÷ 1,000,000) x ppm = grams of chemical or (Grams of chemical x 1,000,000) ÷ ml of solution = ppm

(2) Formulas used to determine hypochlorinator setting

(a) (Ml per min flow rate of water times ppm required dosage) ÷ ppm concentration of solution = ml per min flow rate of feeder.

(b) NOTE: From general formula for dilution (Volume 1 x Concentration 1 = Volume 2 x Concentration 2 or $V_1 \times C_1 = V_2 \times C_2$ or $V_1 \times C_1 \div C_2 = V_2$

(c) EXAMPLES: Flow rate of water = 10 gal per min = 3785

1 Ml per min. 3 ppm dosage is required

2 3 Gal of solution (11,335 ml) containing 16 grams chemical has 1408 ppm (grams of chemical x 1,000,000 ÷ ml of solution)

3 Then 37,850 x 3 = feed flow x 1408. Feeder flow = 80 ml per min.

(3) Procedures for adjusting hypochlorinators

(a) Check lubrication

(b) Check check-valves

(c) Check screens on suction lines

(d) Check belts if applicable

(e) Check all switches for off position

(f) Make sure suction line is in solution

(g) Check to see if feeder is plugged in

APPLICATION:

1. Students will complete WB III-4-P1 (objective 4a)
2. Students will determine rate at which chlorinator should feed solution and, as a team, set the feed rate.

EVALUATION:
Evaluate by oral questions, written questions and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (20 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT: NONE

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/17Jun75	INSTRUCTOR
COURSE NUMBER 3ABR56330	COURSE TITLE Environmental Support Specialist
BLOCK NUMBER III	BLOCK TITLE Operating Principles of Water Treatment Plants

LESSON TITLE
Taste, Odor, and Color Control (Day 22)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
2 Hrs	0.5 Hr	2.5 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
20	6 June 1975	5

STS/CTS REFERENCE

NUMBER	DATE
STS 563X0	28 July 1971

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Jar Test Equipment	None	None	SG III-5 WB III-5-P1

CRITERION OBJECTIVES AND TEACHING STEPS

5a. Demonstrate knowledge relative to cause of, control of, and treatment for taste, odor, and color by writing responses to measurable written items.

(1) Causes of taste, odor, and color

(2) Control and treatment for algae

(3) Removal of dissolved organic materials

(4) Iron and manganese removal

ATC FORM AUG 72 770

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

5b. Using prepared samples, chemicals, and jar test equipment, and following written instructions, as a team, treat water for taste, odor, color, iron, manganese, and algae.

(1) Aeration

(2) Chemical oxidation

(3) Coagulation

(4) Absorption

(5) $CuSO_4$ treatment for algae

Course No: 3ABR56330
Day 22

Branch Approval:
Date: 3 Jul 75

PART II

INTRODUCTION (5 Min)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (100 Min)

PRESENTATION:

5a. Demonstrate knowledge relative to cause of, control of, and treatment for taste, odor, and color by writing responses to measurable written items.

(1) Causes of taste, odor, and color

(a) Dissolved minerals

1 Sodium chloride and similar salts give water a salty or brackish taste

2 Metallic minerals

a Iron and manganese-when well waters containing dissolved Fe and Mn are aerated or chlorinated, these minerals are oxidized and form a red or black precipitate

Low pH waters from mine drainage will be colored due to dissolved iron

Swamp waters may contain iron complexed with colloidal matter causing color which is hard to remove

Corrosion in the distribution system results in a reddish (rust) color at the tap

Certain bacteria use ferrous iron instead of oxygen and produce taste and odor compounds

(b) Dissolved gases-H_2S

- 1 Causes a rotten egg taste and odor
- 2 Sources
    - a Well water
    - b Decaying organic matter
    - c Sulfate reducing bacteria

(c) Dissolved colloidal organic matter

- 1 Products of growth and decaying biological organisms in water supplies a Algae

b Bacteria

c Actinomycetes

2 Vegetable dyes from decaying organic matter cause most natural color in water supplies

3 Phenols-an industrial waste which in small amounts produce a medicinal taste

(d) Suspended solids-such as clay, algae, and precipitated iron, give water an apparent color.

(e) Industrial waste in various forms, especially dissolved organics, may give water taste, odor, and color

(2) Control and treatment for algae

(a) $CuSO_4$ in reservoirs and sedimentation tanks

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- (b) Removed by coagulation, sedimentation, and filtration

- (c) Controlled in plant by chlorination

(3) Removal of dissolved organic materials

- (a) Aeration-some taste and odor compounds may be removed by aeration.

- (b) Coagulation-some dissolved and colloidal organic matter may be absorbed during coagulation especially color

- (c) Chemical oxidation of dissolved organic matter for taste, odor, and color

  - 1 Chlorination

  - 2 Permanganates

- (d) Absorption-most dissolved organics causing taste , odor, and color may be absorbed by activated carbon

(4) Iron and manganese removal

(a) Sources of iron and manganese

1 Well waters with high CO_2 content may contain unoxidized Fe and Mn as the bicarbonates

2 Lakes-in the lower levels of lakes where anaerobic conditions reduce iron to ferrous state

3 Well or surface waters with organic matter result in iron combined with organic matter

4 Corrosive conditions in pipes may release iron to the water

(b) Effects of Fe and Mn

1 Color due to precipitate hydroxides or colloidal organic matter containing iron

2 Taste and odor produced by iron bacteria

3 Slime growths of iron bacteria clogging equipment

(c) Methods of Fe and Mn removal

1 Oxidation, precipitation, sedimentation and filtration

a Oxidize by aeration

b Oxidize by chlorination

c Oxidize in contact beds by catalytic action or by using permanganate

d Low concentrations of unoxidized iron or manganese may be removed by ion exchange

e The lime-soda process for water softening will remove most Fe and Mn

5b. Using prepared samples, chemicals, and jar test equipment, and following written instructions, as a team, treat water for taste, odor, color, iron, manganese, and algae.

(1) Aeration

(a) Removes H_2S (taste and odor)

(b) Oxidizes Fe and Mn

(c) Removes CO_2 thus raising pH and precipitating Fe and Mn

(2) Chemical oxidation

(a) Chlorination

1 Oxidizes Fe and Mn

2 Oxidizes taste, odor, and color and kills algae

(b) Permanganates

1 Oxidizes Fe and Mn

2 Oxidizes taste, odor, and color

(3) Coagulation

(a) Removes precipitated Fe and Mn

(b) Removes color

(4) Absorption

(a) Removes taste and odor

(b) Removes small amounts of color

(5) $CuSO_4$ treatment for algae

APPLICATION:

1. Students will complete WB III-5-P1
2. As a class, use the jar test equipment and chemicals to treat water for taste, odor, Fe, Mn, color, and algae.

EVALUATION:

Evaluate by oral, written questions and/or observation of student's performance during lesson. This may be accomplished at any time during lesson to increase effectiveness.

CONCLUSION (15 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

1. Read SG III-6 and answer questions
2. Read SG-III-7 and answer questions

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/17Jun75	INSTRUCTOR
COURSE NUMBER 3ABR56330	COURSE TITLE Environmental Support Specialist
BLOCK NUMBER III	BLOCK TITLE Operating Principles of Water Treatment Plants

LESSON TITLE
Fluoridation and Defluoridation (Day 23)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
2 Hrs	0.5 Hr	2.5 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
21	6 June 1975	6

STS/CTS REFERENCE

NUMBER	DATE
STS 563X0	28 July 1971

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Chemical Feeders	None	None	SG III-6 WB III-6-P1

CRITERION OBJECTIVES AND TEACHING STEPS

6a. Demonstrate knowledge of principles of fluoridation and defluoridation by writing responses to measurable written items.

(1) Purpose and requirements for fluoridation and defluoridation

(2) Chemicals used for fluoridation

(3) Chemical feeders used for fluoridation

(4) Methods used for defluoridation

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

6b. Given flow rate of water, determine fluoride dosage, concentration of solution, and solution feed rate needed to provide 1 ppm fluorides, and as a member of a team, adjust feeder to deliver required feed.

(1) Determination of feed rate

(2) Adjusting chemical feeder

Course No: 3ABR56330
Day 23

Branch Approval: Bobby Littlejohn
Date: 3 Jul 75

PART II

INTRODUCTION (20 Min)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (85 Min)

PRESENTATION:

6a. Demonstrate knowledge of principles of fluoridation and defluoridation by writing responses to measurable written items.

- (1) Purpose and requirements for fluoridation and defluoridation
  - (a) Fluorides are added to water to prevent tooth decay
  - (b) Residuals are maintained from 0.7 to 1.2 ppm, normally 1 ppm
  - (c) Excess fluorides cause mottling of teeth and excess must be removed
- (2) Chemicals used for fluoridation
  - (a) NaF-a dry powder
  - (b) Na_2SiF_6-a dry powder
  - (c) H_2SiF_6-a liquid

(d) Points of application

(e) Safety precautions

1 Hazards of fluorides

a Toxic

b Corrosive

2 Avoid breathing dust

3 Do not allow chemicals to come in contact with body (especially in open cuts or sores)

4 Wear protective clothing and mask

5 Store chemicals in dry, well ventilated area

(3) Chemical feeders used for fluoridation

(a) Solution feeders (for acid or prepared solutions)

(b) Dry feeders

1 Loss of weight(gravimetric)

2 Volumetric

(4) Methods used for defluoridation

(a) Absorption

1 Bone Char

2 Activated carbon

(b) Precipitation with magnesium and lime

6b. Given flow rate of water, determine fluoride dosage, concentration of solution, and solution feed rate needed to provide 1 ppm fluorides, and as a member of a team, adjust feeder to deliver required feed.

(1) Determination of feed rate

(a) Establish dosage-if treated water has no fluoride, the dosage will be 1 ppm; otherwise, add to equal 1 ppm

(b) Determine flow rate of water in ml per min. Gal per min. x 3784 = ml per minute

(c) Determine concentration of solution in ppm. Per cent of solution x 10,000 = ppm

(d) Flow of water x dosage = solution feed rate x concentration of solution

(2) Adjusting chemical feeder

(a) Changing feed rate

(b) Checking feed rate

APPLICATION:

1. Students will complete WB-6-P1
2. Solve mathematical problems relative to applying fluoride solutions
3. Adjust chemical feeder to determined feed rate.

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (15 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

NONE

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/17Jun75	INSTRUCTOR
COURSE NUMBER 3ABR56330	COURSE TITLE Environmental Support Specialist
BLOCK NUMBER III	BLOCK TITLE Operating Principles of Water Treatment Plants

LESSON TITLE
Water Distribution Systems (Day 23)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
4 Hrs	1.5 Hrs	5.5 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
21	6 June 1975	7

STS/CTS REFERENCE

NUMBER	DATE
STS 563X0	28 July 1971

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
None	None	None	SG III-7 WB III-7-P1 AFM 85-13

CRITERION OBJECTIVES AND TEACHING STEPS

7a. Answer questions relative to function and operation of components of a water distribution system by writing responses to measurable written items.

(1) Pumps

(2) Pipe lines

(3) Storage tanks

(4) Valves and hydrants

(5) Cross connection prevention

(6) Water hammer control

ATC FORM AUG 72 770

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

7b. Using AFM 85-13 and a line drawing showing numbered symbols for pipes and valves, identify type and/or position of valves, size of pipes, and names of components.

(1) Use of utility maps

(2) Reading utility maps

Course No: 3ABR56330
Day 23

Branch Approval: Bobby Littlejohn
Date: 3 Jul 75

PART II

INTRODUCTION (5 Min)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (225 Min)

PRESENTATION:

7a. Answer questions relative to function and operation of components of a water distribution system by writing responses to measurable written items.

(1) Pumps

(a) Booster pumps: Used to raise the pressure in the distribution system

(b) Low lift: Used to pump water from one nonpressure source to another

(c) High lift: Used to pump a gravity source to the distribution system

(d) Well pumps: Can discharge into the water plant, distribution system, or storage.

(2) Pipe lines

(a) Feeder mains supply the distribution mains and storage tanks

(b) Distribution mains are the pipe lines which make up the distribution system

(c) Service lines connect individual buildings to distribution mains.

(3) Storage tanks

(a) Elevated tanks

1 Supply water for emergencies and pump failures

2 Either elevated or on high ground above the highest building

3 Supply pressure in system

(b) Ground storage

1 Store water at or near ground level

- 2 Pumped from these to elevated tanks or directly into system

(c) Pneumatic tanks

- 1 Partially filled with air to maintain pressure
- 2 Takes place of elevated tanks
- 3 Compressed air

(d) Emergency reservoirs

- 1 Used to provide fire protection
- 2 Doesn't feed into system

(4) Valves and hydrants

(a) Valves

- 1 Gate Valves

- a Isolate sections of pipe
- b Opened or closed completely

2 Globe valves

- a Regulate the flow
- b Used in small lines

3 Check valves: Used where the water is allowed to flow in one direction

4 Curb service valves: Used to control water into individual buildings

5 Pressure reducing valves: Used to control water pressure in areas of low elevation.

6 Altitude valves: Used to control the water level in elevated tanks

(b) Hydrants are connected to main feeder line. Normally located on streets 400 ft. apart, so that every building can be reached from 2 hydrants with not more than 300 feet of hoses

1 Standard type for normal street use

2 Flush type or pit mounted for airfield apron use

(5) Prevention of back siphonage (Back flow)

(a) Back siphonage is the backing up of contaminated or polluted water into the potable water system.

(b) Back siphonage conditions frequently occur because of carelessness of users.

(c) Prevent back siphonage by

1 Elimination of connection
2 Separation by air gap
3 Back flow preventer
4 Testing and maintenance

(6) Water hammer control

(a) Water hammer is a rapid pressure fluctuation above and below the line pressure in a closed system caused by rapid closing of valves.

(b) Water hammer can be controlled by installation of a valve that cannot be closed too quickly or improperly. Instructions to operating personnel can frequently relieve the condition

(c) Surge chamber

7b. Using AFM 85-13 and a line drawing showing numbered symbols for pipes and valves, identify type and/or position of valves, size of pipes, and names of components.

(1) Use of utility maps

(a) Utility maps are needed to show location of various pipes and valves

(b) The mind of man forgets but maps can always be used to show precise location of components

(c) Changes should be made on a utility map every time a new line is laid or a readjustment of the old one is made

(2) Reading of utility maps

(a) Symbols are used to show location of valves, mains, and other components of a water distribution system.

(b) Each base normally shows meaning of symbols on a legend on the map.

APPLICATION:

1. Give student's a diagram drawing of a distribution system. Have them to identify different symbols used to show various components.
2. Have students complete WB 3ABR56330-III-7-P1 pages 20 and 21

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

Read SC 3ABR56330-III-8

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/17Jun75	INSTRUCTOR
COURSE NUMBER 3ABR56330	COURSE TITLE Environmental Support Specialist
BLOCK NUMBER III	BLOCK TITLE Operating Principles of Water Treatment Plants

LESSON TITLE
Internal Corrosion and Scale (Days 24 and 25)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
10 Hrs	4 Hrs	14 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
22	6 June 1975	8

STS/CTS REFERENCE

NUMBER	DATE
STS 563X0	28 July 1971

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Automatic pH Controller Trainer	None	None	SG III-8 WB III-8-P1 Automatic pH Control Operating Manual

CRITERION OBJECTIVES AND TEACHING STEPS

8a. Demonstrate a knowledge of internal scale and corrosion and the causes and treatment for, by matching terms or items of information with related phrases or statements.

(1) Causes of scale

(2) Causes of corrosion

(3) Types of water using equipment

(4) Scale and corrosion control in open recirculation systems (cooling towers)

(5) Scale and corrosion control in closed recirculation systems

(6) Scale and corrosion control in boilers

ATC FORM AUG 72 770

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

8b. Following written instructions as a class team member, operate the pH controller trainer to adjust the water to a pH of 10 ± .5 pH unit.

(1) Purpose of pH controller

(2) Components and principles of operation

(3) Operational procedures

Course No: 3ABR56330
Days 24 and 25

Branch Approval: Bobby Littlejohn
Date: 3 Jul 75

PART II

INTRODUCTION (30 Min)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (540 Min)

PRESENTATION:

8a. Demonstrate a knowledge of internal scale and corrosion and the causes and treatment for, by matching terms or items of information with related phrases or statements.

- (1) Causes of scale
  - (a) Impurities in water cause scale
    - 1 Those which cause hardness
      - a Calcium
      - b Magnesium
    - 2 Fe-Mn
    - 3 Silica
    - 4 Suspended solids

(b) Forms of scale

- 1 Pure mineral scale
    - a $CaCO_3$-soft, chalky
    - b $CuSO_4$-hard, sticky, especially on hot surfaces
    - c $Mg (OH)$
    - d SiO_2-hard, glass-like deposit
- 2 Mixed scale-corrosion products (may contain the normally suspended solids)
- 3 Combinations of mineral scale bound together by silica to form a hard scale

(c) Conditions affecting scaling

1 Concentration of ions which combine to form scale-Ca, Mg, SiO_2, CO_3, SO_4, and OH

2 pH

3 Temperature of water

4 Temperature of metal surface

(2) Causes of corrosion

(a) Definition of corrosion.

(b) Direct chemical attack

1 Oxygen attack

2 Acid attack

(c) Electro-chemical attack (Galvanic cell)

1 Essentials of a galvanic cell

  a Anode-metal or area which corrodes

  b Cathode-where reduction of H+ takes place

  c Metal bond-connects electrodes

  d Electrolyte-(salt or acid solution)

  e Depolarizer-(normally dissolved oxygen must be present) removes H_2 from cathode

2 Conditions favorable for corrosion

  a Low pH (acid)

  b CO_2-(forming acid)

c Dissolved oxygen

d Bimetallic coupling

(3) Types of water using equipment

(a) Once through systems

1 Water distribution systems

2 Hot water heaters
NOTE: Treatment as covered in softening and stabilization.

(b) Open recirculation systems

1 Cooling towers

2 Ponds or lakes

(c) Closed recirculation systems

1 Internal combustion engine cooling systems

2 Hot water heating systems

3 Refrigeration chilled water systems

(4) Scale and corrosion control in open recirculation systems (cooling towers)

(a) Factors affecting scale and corrosion in cooling towers

1 Concentration of solids due to loss of water by evaporation

2 Saturation of water with dissolved oxygen

3 Possible high temperatures

4 Algae and bacterial growth in tower and lines

5 Electro-chemical corrosion of different metals

(b) Methods of control

1 Softening of make-up water

2 Blow down to limit concentration of solids

3 pH adjustment to prevent $CaCO_3$ precipitation

4 Polyphosphates to keep Ca and Mg in solution and as a corrosion inhibitor

5 Chlorination or other chemicals to control biological growths

(5) Scale and corrosion control in closed recirculation systems

(a) Since a minimum of make up water is used, scale is little problem

(b) Corrosion control

1 Corrosion inhibitors

a Chromates-cannot be used with permanent type antifreeze-toxic

b Nitrates-can be used with antifreeze

(6) Scale and corrosion controls in boilers

(a) Factors causing scale and corrosion in boilers

1 Precipitation of scale due to high temperature (in boiler)

2 Concentration of solids (in boiler) due to steam losses

3 Break down of HCO_3 to precipitate $CaCO_3$ and form CO_2 which causes corrosion in steam and condensation lines

4 Dissolved oxygen in boiler water and in steam lines causing corrosion

(b) Methods of control

1 Removal of hardness and carbonate alkalinity from make-up water

2 Deaerate to remove O_2

3 Adjust pH with NaOH

4 Blow Down of boiler water to prevent solids buildup

5 Add sodium sulfite to remove dissolved oxygen-
$Na_2SO_3 + Na_2SO_4$

6 Add neutralizing amines to neutralize CO_2

7 Add filming amines to form protective coating on steam and condensate lines

CONCLUSION (DAY 24)

SUMMARY:

STUDY ASSIGNMENT:

INTRODUCTION (DAY 25)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

8b. Following written instructions as a class team member, operate the pH controller trainer to adjust water to a pH of 10 ± .5pH unit.

(1) Purpose of pH controller

(a) This specific unit is used to adjust pH of boiler water

(b) Other systems with similar equipment

1 Cooling tower water

2 Acid feed for stability of once through systems using lime softening

(2) Components and principles of operation

(a) Caustic tank

(b) Pump and control assembly

(c) Mixing chamber

(d) Sensing chamber

(e) Amplifier

(f) Recorder controller

(3) Operational procedures

(a) Preinspection and service

(b) Operational instructions

(c) Safety

1 Electrical

2 Chemical

APPLICATION:

The students will complete WB-3-P1 and operate the pH trainer to adjust pH of water

EVALUATION:

Evaluate by oral, written questions and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (30 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

Read SG IV-1

Block Test:

17-5

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCKTC/17Jun75	INSTRUCTOR
COURSE NUMBER 3ABR56330	COURSE TITLE Environmental Support Specialist
BLOCK NUMBER IV	BLOCK TITLE Specialized Water Treatment

LESSON TITLE
Ion Exchangers and Controls (Days 26, 27, 28, and 29)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
24 Hours	8 Hours	32 Hours

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
24	6 June 1975	1

STS/CTS REFERENCE

NUMBER	DATE
STS 563X0	28 July 1971

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Sodium Cation Exchanger Hydrogen Cation Exchanger Mixed Bed Demineralizer Water Softener Trainer Dual Bed Demineralizer	None	None	SG IV-1 WB IV-1-P1 563X0 Career Ladder, Servicing of Ion Exchangers AFM 85-13 SAFB 169 TVS 56-7a

CRITERION OBJECTIVES AND TEACHING STEPS

1a. Using an ion exchanger unit, trace the water flow through the unit for each cycle of operation.

(1) Purpose of ion exchangers and demineralizers

(2) Theory of ionization

(3) Characteristics of resins

(4) Types of exchangers

(5) Construction features

(6) Cycles of operation

ATC FORM AUG 72 770

1b. Using an ion exchanger unit, adjust the controls to direct water flow through the unit for each cycle of operation.

(1) Preoperational inspections

(2) Starting adjustments

(3) Operational adjustments

(4) Shutdown adjustments

(5) Safety precautions

1c. Using a dual bed or mixed bed demineralizer, observing safety precautions and working as a team, regenerate the unit and place in service.

(1) Need for regeneration

(2) Backwash procedures

(3) Regeneration preparation

(4) Function of controls and instruments

(5) Safety in handling chemicals

(6) Quality control measures

1d. Using the written instructions in part II, section 13, AFM 85-13, inspect the ion exchanger units and perform the required maintenance.

(1) Multiport valves and distribution fittings

(2) Ejectors and brine solution

(3) Service conditions

(4) Safety precautions

Course No: 3ABR56330
Days 26, 27, 28, & 29

Branch Approval:
Date: 17 Jul 75

PART II

INTRODUCTION (10 Minutes)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (1420 minutes)

PRESENTATION:

1a. Using an ion exchanger unit, trace the water flow through the unit for each cycle of operation.

(1) Purpose of ion exchangers and demineralizers

(2) Theory of ionization

(3) Characteristics of resins

(a) Natural sand is also known as glauconite (green sand). It is green-grey in color, and is granular in shape

(b) Manmade resins have a higher capacity to exchange than natural sand

1 Sulfonated polystyrene is gold-brown in color and is shaped in a spherical bead

2 Silica-aluminum compound is manmade green sand. It is white in color and granular in shape

3 Polamine polystyrene is amber in color and granular in shape

4 Quaternary-amine polystyrene is yellowish in color and is spherical in shape

(4) Types of exchangers

(a) Cation

1 Sodium cation is to remove Ca & Mg only

2 Hydrogen cation will remove Ca, Mg, Fe, alkalinity and lower TDS

(b) Anion

1 Weak base will remove strong acids only

2 Strong base will remove all acids

(5) Construction features

(a) Tank

(b) Underdrain

(c) Effluent distributor

(d) Support bed

(e) Exchanger material

(f) Freeboard space

(g) Influent distributor

(h) Multiport valve

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(i) Rate of flow indicator

(j) Flow meter

(k) Regenerant tank

(6) Cycles of operation

(a) Backwash

(b) Chemical injection

(c) Slow rinse

(d) Final rinse

(e) Service

APPLICATION:

Using an ion exchanger unit, trace the flow of water through the unit in all cycles of operation.

CONCLUSION (DAY 26)

SUMMARY:

STUDY ASSIGNMENT:

INTRODUCTION (Day 27)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

1b. Using an ion exchanger unit, adjust the controls to direct water flow through the unit for each cycle of operation.

(1) Preoperational inspections

(2) Starting adjustments

(3) Operation adjustments

(4) Shutdown adjustments

(a) Close influent valve

(b) Close effluent valve

(c) Secure area

(5) Safety precautions

(a) Always pour acid into water when diluting

(b) Use goggles/face shield and apron when diluting acids

(c) Do not breath the vapors from acids

(d) If you get acids or lye water on your hands, wash them gently using a lot of water as these will cause severe burns

APPLICATION:

Using an ion exchanger unit, adjust the controls to direct water flow through the unit for each cycle of operation.

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CONCLUSION (Day 27)

SUMMARY:

STUDY ASSIGNMENT:

Review SG 3ABR56330-IV-1, Ion Exchangers

INTRODUCTION (Day 28)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT

REVIEW:

OVERVIEW:

MOTIVATION:

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PRESENTATION:

1c. Using a dual-bed or mixed-bed demineralizer, observing safety precautions, and working as a team, regenerate the unit and place in service.

(1) Need for regeneration

(2) Backwash procedures

(3) Regeneration preparation

(4) Functions of controls and instruments

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(5) Safety in handling chemicals

(6) Quality control measures

APPLICATION:

Using a dual-bed or mixed-bed demineralizer, and working as a team(3-man), regenerate the unit and place it into service position.

CONCLUSION (Day 28)

SUMMARY:

STUDY ASSIGNMENT:

Review SG 3ABR56330-IV-1, Ion Exchangers

INTRODUCTION (Day 29)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

1d. Using the written instructions in part H, section 13, AFM 85-13, inspect the ion exchanger units and perform the required maintenance

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(1) Multiport valves and distribution fittings

(2) Ejectors and brine solution

(3) Service conditions

(4) Safety precautions

APPLICATION:

Using the instructions in AFM 85-13, Part H, Section 13, inspect the demineralizer units and perform the required maintenance.

EVALUATION:

Evaluate by oral, written questions, and/or observation of students performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR56330-IV-2, Electrodialysis Demineralization
SG 3ABR56330-IV-3, Specialized Water Treatment

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/17Jun75	INSTRUCTOR
COURSE NUMBER 3ABR56830	COURSE TITLE Environmental Support Specialist
BLOCK NUMBER IV	BLOCK TITLE Specialized Water Treatment

LESSON TITLE
Electrodialysis Demineralization (Day 30)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
4 Hours	1.5 Hours	5.5 Hours

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
25	6 June 1975	2

STS/CTS REFERENCE

NUMBER	DATE
STS 563X0	28 July 1971

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Electrodialysis Demineralizer	None	None	SG IV-2 WB IV-2-P1

CRITERION OBJECTIVES AND TEACHING STEPS

2a. Following written instructions, inspect, start, and stop the electrodialysis unit.

(1) Principles of operation

(2) Major components

(3) Operational procedures

(4) Safety precautions

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

2b. Following written instructions and working as a team, assemble a repeated section of a membrane stack.

(1) Stack malfunction

(2) Disassembly procedures

(3) Assembly procedures

(4) Operational check

(5) Safety precautions

Course No: 3ABR56330
Day 30

Branch Approval:
Date: 17 Jul 75

PART II

INTRODUCTION (5 Min)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (230 Min)

PRESENTATION:

2a. Following written instructions, inspect, start, and stop the electrodialysis unit.

(1) Principles of operation

(2) Major components

(a) Membrane stack

(b) DC rectifier

(c) Centrifugal pump

(d) Inlet filter

(e) Rate of flow meter

(f) Pressure control valve

(g) Conductivity meter

(h) Chemicals used

1 Acids

2 Calgon

(i) Dual chemical feeder

(j) External piping provides

1 A dilute stream

2 A concentrate stream

3 An electrode stream

(3) Operational procedures

(4) Safety precautions

(a) Use extreme caution around the DC current. Be sure to have rubber mats around the unit; remove all jewelry before starting

(b) Use caution when handling acid while cleaning the stack

2b. Following written instructions and working as a team, assemble a repeated section of a membrane stack

(1) Stack malfunctions

(a) Deposits of scale causing a salt block

(b) Spacers being placed wrong

(c) Membranes cracked or broken

(2) Disassembly procedures

(3) Assembly procedures

(a) Carefully aline the membranes and spacers so that the manifold holes form a vertical flow header for the entering streams.

(b) Replace the top electrode section and top end blocks in the reverse order of disassembly

(c) Grease edges of the electrode with silicone grease

(d) Tighten binding bolts alternately and only enough to stop excessive leaking with the pump on.

(4) Operational check

(5) Safety Precautions

APPLICATION:

Using the provided checklist, each student will inspect, start, and stop the electrodialysis unit.

Using the chart provided and the workbook WB 3ABR56330-IV-2-P1, working as a team, assemble a repeated section of a membrane stack.

EVALUATION:

Evaluate by oral, written questions and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (5 Min)

SUMMARY:

REMOTIVATION:

Reemphasize why students need to remember and apply what was learned today.

STUDY ASSIGNMENT: NONE

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/17Jun75	INSTRUCTOR
COURSE NUMBER 3ABR56330	COURSE TITLE Environmental Support Specialist
BLOCK NUMBER IV	BLOCK TITLE Specialized Water Treatment

LESSON TITLE
Specialized Water Treatment (Day 30)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
2 Hrs	0.5 Hrs	2.5 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
26	6 June 1975	3

STS/CTS REFERENCE

NUMBER	DATE
STS 563X0	28 July 1971

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
None	None	None	SG IV-3 WB IV-3-P1

CRITERION OBJECTIVES AND TEACHING STEPS

3a. Using related information, state the application of the reverse osmosis process of water treatment.

(1) Methods of treating brackish water

(2) Principles of reverse osmosis

(3) Application of reverse osmosis

(4) Disadvantages of reverse osmosis

ATC FORM AUG 72 770

Course No: 3ABR56330 Branch Approval: Bobby Littlejohn
Day 30 Date: 17 Jul 78

PART II

INTRODUCTION (5 Min)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (110 Min)

PRESENTATION:

3a. Using related information, state the application of the reverse osmosis process of water treatment.

(1) Methods of treating brackish water

(a) Reverse osmosis

(b) Freezing

(c) Atomic distillation

(2) Principles of reverse osmosis

(a) In reverse osmosis, pressure is applied to a stream of contaminated water, driving purified water through a semipermeable membrane. The water left behind carries away the impurities. Since the process does not require boiling or freezing it uses much less energy than other systems.

(b) Reverse osmosis is purely a mechanical process which can be used for the purification and recovery of water and other liquids

(3) Applications of reverse osmosis

(a) Water softening

(b) Treatment of boiler feed water

(c) Processing of industrial chemicals

(d) Removal of radioactive contaminants

(e) Portable water units

(f) Demineralizing sea water

(g) Tertiary treatment of sewage

(h) Water purification for homes, motels, and industries

(4) Disadvantages of reverse osmosis

(a) High initial cost

(b) Membranes coat easily with solids

(c) Turbid water must be filtered

(d) Requires high pressure source

APPLICATION:

Complete WB 3ABR56330-IV-3-P1, Specialized Water Treatment.

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (5 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR56330-IV-4, Distillation of Water

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/17Jun75	INSTRUCTOR
COURSE NUMBER 3ABR56330	COURSE TITLE Environmental Support Specialist
BLOCK NUMBER IV	BLOCK TITLE Specialized Water Treatment

LESSON TITLE
Distillation (Days 31 and 32)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
12 Hrs	4 Hrs	16 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
27	6 June 1975	4

STS/CTS REFERENCE

NUMBER	DATE
STS 563X0	28 July 1971

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Meco Vapor Compression Distillation Trainer	None	None	SG IV-4 WB IV-4-P1 WB IV-4-P2 WB IV-4-P3 TVS 56-5a MN 7489c

CRITERION OBJECTIVES AND TEACHING STEPS

4a. Using related information, state the need for conversion of saline water and methods of distillation.

(1) Need for conversion of saline water

(2) Methods of distillation

(3) Terms used in distillation

ATC FORM AUG 73 770

4b. Following written instructions and working as a team, operate the distillation equipment to produce salt free water.

(1) Operation principles

(2) Flow pattern

(3) Operating conditions and services

(4) Operational procedures

4c. Following written and oral instructions and working as a team, inspect, clean, and perform required maintenance of distillation units.

(1) Inspection procedures

(2) Recording services performed

(3) Cleaning equipment and tools

(4) Cleaning methods and procedures

(5) Troubleshooting procedures

(6) Maintenance procedures

(7) Use and care of maintenance equipment and tools

(8) Protective equipment

(9) Safety precautions when handling chemicals and using tools

(10) Operational check

Course No: 3ABR56330
Days 31 and 32

Branch Approval:
Date: 19 Jul 65

PART II

INTRODUCTION (10 Minutes)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (11 Hrs 40 Minutes)

PRESENTATION:

4a. Using related information, state the need for conversion of saline water and methods of distillation.

(1) The need for conversion saline water

(a) Little or no fresh water available

(b) Water needed for specific purpose

(c) Fresh water decreasing, demand increasing

(2) Methods of distillation

(a) Natural distillation is carried out on a large scale. The water is taken from the surface supply and is condensed in the atmosphere and precipitated in the form of rain or snow

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(b) Manmade units

1 Single stage distillation: Most simple method. Not as efficient as a multiple effect unit.

2 Multiple effect unit: Uses heat from one unit to heat water for another unit

3 Expedient distillation: One that is built hurriedly to meet an emergency situation

4 Vapor compression unit: A compressor is added to a basic unit to increase efficiency.

(3) Terms used in distillation

4b. Following written instructions and working as a team, operate the distillation equipment to produce salt free water

(1) Operation principles:

(2) Flow pattern

(a) Passes first through the heat exchanger

(b) From the heat exchanger it passes through the vent condenser to the evaporator/immersion heater where it boils and the steam rises. The brine is drawn off by the blow-down pump and discharged to waste.

(c) The steam is passed through a mesh separator in the vapor head. The dry steam is drawn from the head thru the vapor compressor.

(d) The latent heat of the compressed steam is transferred thru the tube walls to the boiling water.

CONCLUSION (Day 31)

SUMMARY:

STUDY ASSIGNMENT:

Review SG 3ABR56330-IV-4, Distillation of Water

INTRODUCTION (Day 32)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

4b. (continued) Following written instructions and working as a team, operate the distillation equipment to produce salt free water.

(3) Operating conditions and service

(a) Make pre-operational check

1 Check for physical damage

2 Check for loose connections

(b) Perform service outlined in SG 3ABR56330-IV-4, section B

(4) Operation procedures

(a) Manual

(b) Automatic

4c. Following written and oral instructions and working as a team, inspect, clean, and perform required maintenance of distillation units

(1) Inspection procedures

(2) Recording services performed

(a) There is not a standard form for the distillation unit. Each base will provide their own.

(b) A sample is shown in the SG 3ABR56330-IV-4, page 71. Other columns could be added to include

1 Date unit cleaned

2 Gallons of distilled water produced

3 Hours of operation

4 Operators name

(3) Cleaning equipment and tools

- (a) Electric drill
- (b) Water feeding attachment
- (c) Coupling shaft
- (d) Scale drill/wire tube brush
- (e) Scrubbing brush
- (f) Rubber pails, gloves, apron, and face shield

(4) Cleaning methods and procedures

- (a) Chemicals
  - 1 Muriatic acid
  - 2 Niter cake

(b) Mechanical

  1 Use fluted reamers and electric drill

  2 Use scrubbing brush on the bottom plate and in the steam chest

(5) Troubleshooting procedures

(6) Maintenance procedures

(7) Use and care of maintenance equipment and tools

(8) Protective equipment

  (a) Rubber gloves (acid resistant)

  (b) Rubber or acid resistant apron

  (c) Face shield

(d) Rubber mats around units

(9) Safety precautions when handling chemicals and using tools

(a) Acids used for descaling are very dangerous. Handle carefully.

(b) Use tools provided by the manufacturer for this unit

(10) Operational check

(a) Perform after maintenance is completed

(b) Outlined in WB 3ABR56330-IV-4-P1

APPLICATION:

Complete WB 3ABR56330-IV-P1, Distillation Terms. Using WB 3ABR56330-IV-4-P3, trace the flow of water through a distillation unit.

As a two man team, and using WB 3ABR56330-IV-4-P2, perform pre-operational inspection, record services performed, and operate the distillation unit.

Following written/oral instructions and working as a 3-man team, inspect, clean and perform required maintenance on the distillation unit. (Use WB 3ABR56330-IV-4-P2

EVALUATION:

Evaluate by oral, written questions, and/or observation of students performance during lesson. This may be accomplished at any time during lesson to increased effectiveness.

CONCLUSION (10 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR56330-1V-5, Field Water Treatment Equipment

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/17Jun75	INSTRUCTOR
COURSE NUMBER 3ABR56330	COURSE TITLE Environmental Support Specialist
BLOCK NUMBER IV	BLOCK TITLE Specialized Water Treatment

LESSON TITLE
Field Water Purification Unit (Days 33, 34, and 35)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
16 Hrs	4 Hrs	20 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
28	6 June 1975	5

STS/CTS REFERENCE

NUMBER	DATE
STS 563X0	28 July 1971

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Water Purification Unit, 600 GPH Trailer Mounted	None	None	SG IV-5 WB IV-5-P1 TO 40W4-9-1 TVS 56-3

CRITERION OBJECTIVES AND TEACHING STEPS

5a. Using related information, state the purpose and application of the field water purification unit.

(1) Purpose of unit

(2) Application of unit

5b. Following procedures in TO 40W4-9-1, working as a team, perform a preoperational inspection and service of the field water purification unit.

(1) Component identification

(2) Chemicals used with unit

(3) Service procedures

(4) Preoperational checks

(5) Service equipment

(6) Safety precautions during service activities

5c. Following procedures in TO 40W4-9-1, working as a team, operate the field water purification unit.

(1) Preliminary set up

(2) Adjustment of slurry feed system

(3) Adjustment of solution feeders

(4) Starting the unit

(5) Operational procedures

(6) Shutting down unit

(7) Post inspection

5d. Following procedures outlined in TO 40W4-9-1, clean the water purification unit and position the valves to allow precoat of the DE filter.

(1) Maintenance requirements

(2) Filter system and assemblies

(3) Adjustment of controls

(4) Cleaning procedures

(5) Transporting unit

Course No: 3ABR56330
Days 33, 34, & 35

Branch Approval:
Date: 17 Jul 75

PART II

INTRODUCTION (10 Min)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (940 Min)

PRESENTATION:

5a. Using related information, state the purpose and application of the field water purification unit.

(1) Purpose of unit

(2) Application of unit:

5b. Following procedures in TO 40W4-9-1, working as a team, perform a preoperational inspection and service of the field water purification unit.

(1) Component identification

(a) Identify and discuss the function of the following components of the unit

1 Drive motor

2 Speed reducer

3 Air pump

4 Influent flow controls

5 Aspirator

6 Influent launder

7 Downcomer tube-mixing tube

8 Agitator shaft and disk

9 Bearing support

10 Baffle and baffle ring

11 Sludge blanket zone-separator zone

12 Clear water zone

13 Effluent launder

14 Wet well tank

15 Weir box

16 Sludge concentrator tank

17 Slurry feeder

18 Solution feeder

19 Filter pump

20 Pipes and fittings

21 Electrical box

22 Bridge rail

(b) Identify the following support equipment and discuss the purpose of each

1 Filter

    a Precoat funnel

    b Pressure gage

    c Wash ring

    d Filter housing

    e Filter elements

    f Air release valve

2 Generator

3 Supply pump

4 Distributor pump

5 Hoses

6 Strainer

7 Test equipment

(2) Chemicals used with unit

(a) Ferric chloride as a coagulant

(b) Pulverized limestone as a coagulant aid

(c) Calcium hypochlorite as a disinfectant

(d) Diatomaceous earth as a filter aid

(e) Activated carbon as an absorber of taste and odor

(3) Service procedures

(4) Preoperational checks

(5) Service equipment

(6) Safety precautions during service activities.

CONCLUSION (Day 33)

SUMMARY:

STUDY ASSIGNMENT:

SG 3ABR56330-IV-5, Field Water Treatment Equipment

INTRODUCTION (Day 34)

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

5c. Following procedures in TO 40W4-9-1, working as a team, operate the field water purification unit.

(1) Preliminary set up

222

(a) Set up storage tank

(b) Connect and position hoses

1 Raw water and strainer

2 Wastewater

3 Recirculating

4 Filter influent

5 Storage tank influent

6 Distribution

(2) Adjustment of slurry feed system

(3) Adjustment of solution feeders

(a) Ferric chloride

    - (b) Calcium hypochlorite
    - (c) Filling chemical slurry feeder

- (4) Starting the unit
    - (a) Start raw water flow
    - (b) Start chemical solution feeder
    - (c) Start the Agitator motor after one foot of water is in the erdlator tank
    - (d) Adjust water flow to slurry feeder
    - (f) Adjust air flow to slurry feeder
    - (g) Set slurry feed timer
    - (h) Level effluent launder

(i) Adjust effluent flow to 10 GPM

(j) Reposition valves as necessary

(k) Start filter operation

  1 Preliminary positioning of valves

  2 Precoat filter

  3 Position valve for filtering

  4 Adjust filter air flow

(5) Operational procedures

  (a) Recharging chemical slurry feeder

  (b) Recharging chemical solution feeder

(c) Adjustment of chemical dosages

(d) Slurry blanket rotation

(e) Slurry level control and sludge removal

(f) Backwash filter

(6) Shutting down unit

(a) First, backwash filter

(b) Shutdown filter pump

(c) Shutdown the erdlator

(7) Post inspection

CONCLUSION (Day 34)

SUMMARY:

STUDY ASSIGNMENT:

INTRODUCTION (Day 35)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

5d. Following procedures outlined in TO 40W4-9-1, clean the water purification unit and position the valves to allow precoat of the DE filter.

(1) Maintenance requirements

(2) Filter system and assemblies

(3) Adjustment of controls

- (a) Set valves for draining
- (b) Shut all breakers to "OFF"
- (c) Clean chemical feeder

(4) Cleaning procedures

- (a) Put all hoses away
- (b) Rinse inside erdlator
- (c) Wipe down outer shell
- (d) Clean area where unit is

(5) Transporting unit

(1) Have students accomplish WB-IV-5-P1

(2) Have students observe safety precautions during service activities

(3) Have students follow procedures outlined in TO 40W4-9-1 and work as a member of a team to perform preoperational inspection and service of the water purification unit.

(4) Following procedures outlined in TO 40W4-9-1 and working as a team, operate the field water purification unit

(5) Following procedures outlined in TO 40W4-9-1, clean the water purification unit, and position the valves to allow precoating of the DE filter.

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR56330-V-1, Field Sanitation

SG 3ABR56330-V-2, Classes and Sources of Waste

SG 3ABR56330-V-3, Composition and Characteristics of Sewage

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PREPARE THE MAN

STUDY GUIDES 3ABR~~56330~~ 51631-III-1 Thru 8

Department of Civil Engineering Training

175

Engineer Environmental Support Specialist

OPERATING PRINCIPLES OF WATER TREATMENT PLANTS

February 1972

SHEPPARD AIR FORCE BASE

Designed For ATC Course Use

DO NOT USE ON THE JOB

OPERATING PRINCIPLES OF WATER TREATMENT PLANTS

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This publication supersedes SG 3ABR56330-1, 9 April 1970; SG 3ABR56330-III-2, 9 September 1970; SG 3ABR56330-III-3, 6 April 1970; SG 3ABR56330-III-4, 26 March 1970: SG 3ABR56330-III-5, 1 April 1970; SG 3ABR56330-III-6, 26 March 1970: SG 3ABR56330-III-7, 8 April 1970: SG 3ABR56330-IV-5, 17 February 1971.

Dept of Civil Engineering Training
Sheppard AFB, Texas

SG 3ABR56330-III-1
22 February 1972

PRINCIPLES OF WATER TREATMENT PLANT

OBJECTIVE

The purpose of this study guide is to assist you in identifying the major units in a water treatment plant. It will also aid you in learning the principles behind treatment.

INTRODUCTION

Absolutely pure water is never found in nature. For military use, water must be free of disease producing organisms, poisons, and excessive amounts of minerals or organic matter. Under these conditions, the water is safe for drinking, cooking, and washing. When time and equipment permit, the water should be clear, cool, and free of objectionable tastes and odors. Every effort should be made to provide water of excellent quality because of the effect it has on the health and morale of men.

An adequate supply of water is essential to the success of any operation. Man cannot live without water; it is more essential to him than food. During times of extreme heat, lack of water may present problems. The water must be rendered safe for human consumption by treatment to eliminate disease, germs, and injurious chemicals.

This study guide will acquaint you with water treatment plant equipment and how it is used. It will be discussed under the following subjects:

- MAJOR PLANT UNITS
- OPERATING PRINCIPLES

This study guide will not cover all the information you need to know, and study of additional material is recommended.

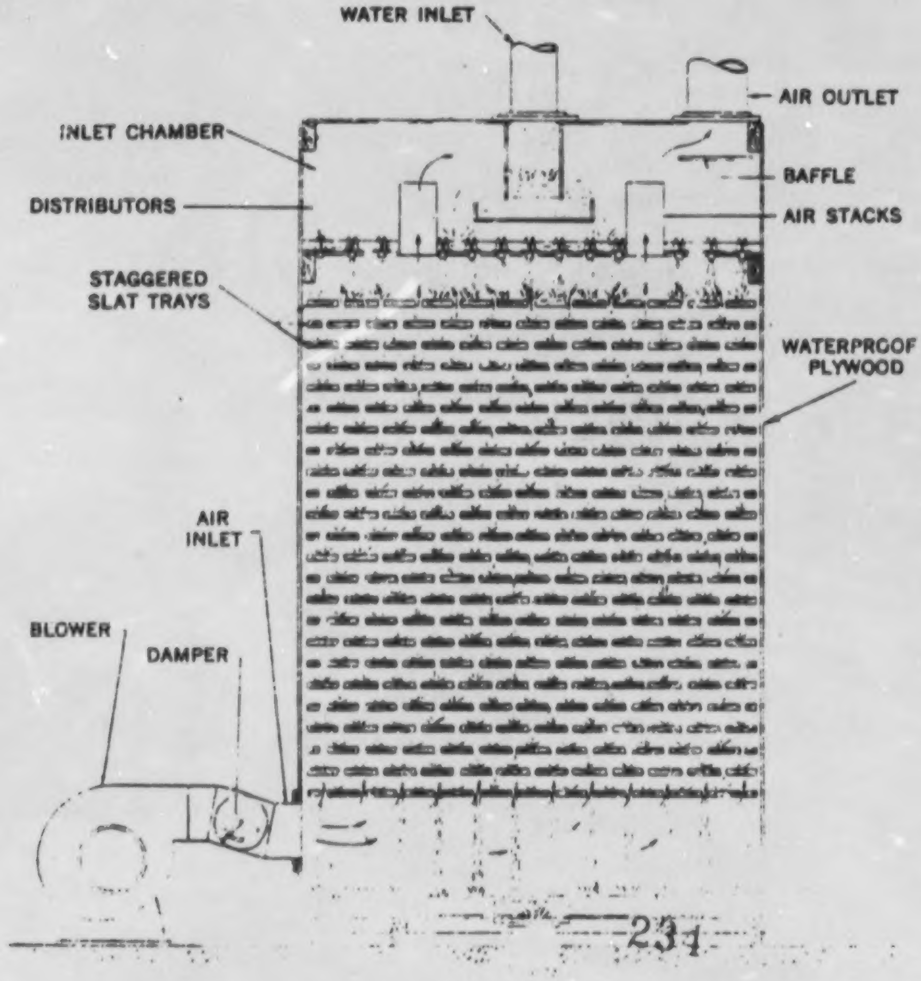
MAJOR PLANT UNITS

All water plants do not contain the same identical equipment. Some plants have more or less equipment than others. They are designed according to the amount and type of minerals and organic matter the water contains.

Aerator

Aeration consists essentially of exposing as much water surface as possible to the air. During aeration, gases dissolved in the water supply are released to the atmosphere; soluble iron salts are oxidized and become insoluble so they can be removed by settling. Aeration raises the pH by eliminating dissolved carbon dioxide but increases corrosiveness by increasing the amount of dissolved oxygen.

Types of aeration consist of overflowing trays or trays containing slats or coke over which water is sprayed (see figure 1). Other methods of aeration include spraying water up over a shallow receiving basin. and forcing air into a basin with diffusers or mechanical pump type aeration. The operation of most aerators is practically automatic. If the water is not to be filtered after aeration, it must be protected from insects and other foreign matter by the use of fine screens.


WATER INLET
AIR OUTLET
INLET CHAMBER
BAFFLE
DISTRIBUTORS
AIR STACKS
STAGGERED SLAT TRAYS
WATERPROOF PLYWOOD
AIR INLET
BLOWER
DAMPER

Rapid Mixer

The more quickly the coagulants can be uniformly mixed with the water to be treated, the more rapidly the chemical reaction will take place. In water treatment this practice is called rapid mixing. The compartment in which this process takes place is known as the mixing chamber or basin. The devices by which the rapid mixing is accomplished are known as rapid or flash mixers (see figure 2). These include pumps, aero-mixers, turbo-mixers, hydraulic pumps, an agitated mixing chamber, and mechanical stirrers.

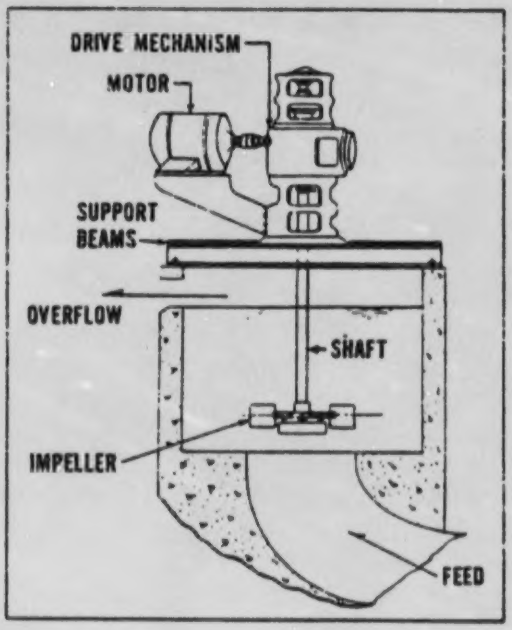


Figure 2. Flash Mixer

Slow Mixer (Flocculator)

The slow mixer or flocculator which follows the addition and mixing of the coagulant, is to promote the growth of the floc particles and to provide opportunity for contact between the floc and the suspended particles causing turbidity. The increased weight of the floc results not only from the increased size of the floc but also from the absorption of turbidity particles on the enlarged precipitate as it moves through the water. The more opportunity floc has to contact the suspended turbidity, the more efficient the removal will be. Too much agitation will break up the floc

Method of Operation. Water containing the well mixed coagulant flows continuously into the flocculation chamber through the inlet ports. As it reaches the first set of flocculators, suspended particles are displaced by the motion of the paddles and subjected to the slow stirring action of eddies and rolling motion of the water induced by the motion of the blades (see figure 3). At the same time the water moves through the unit to the next set of flocculators. The next set, which is usually operated slower, causes further flocculation. This causes them to increase in size and settle more rapidly. It should usually take 20 to 30 minutes for the water to travel the length of the unit. It will then be ready for the settling tank.

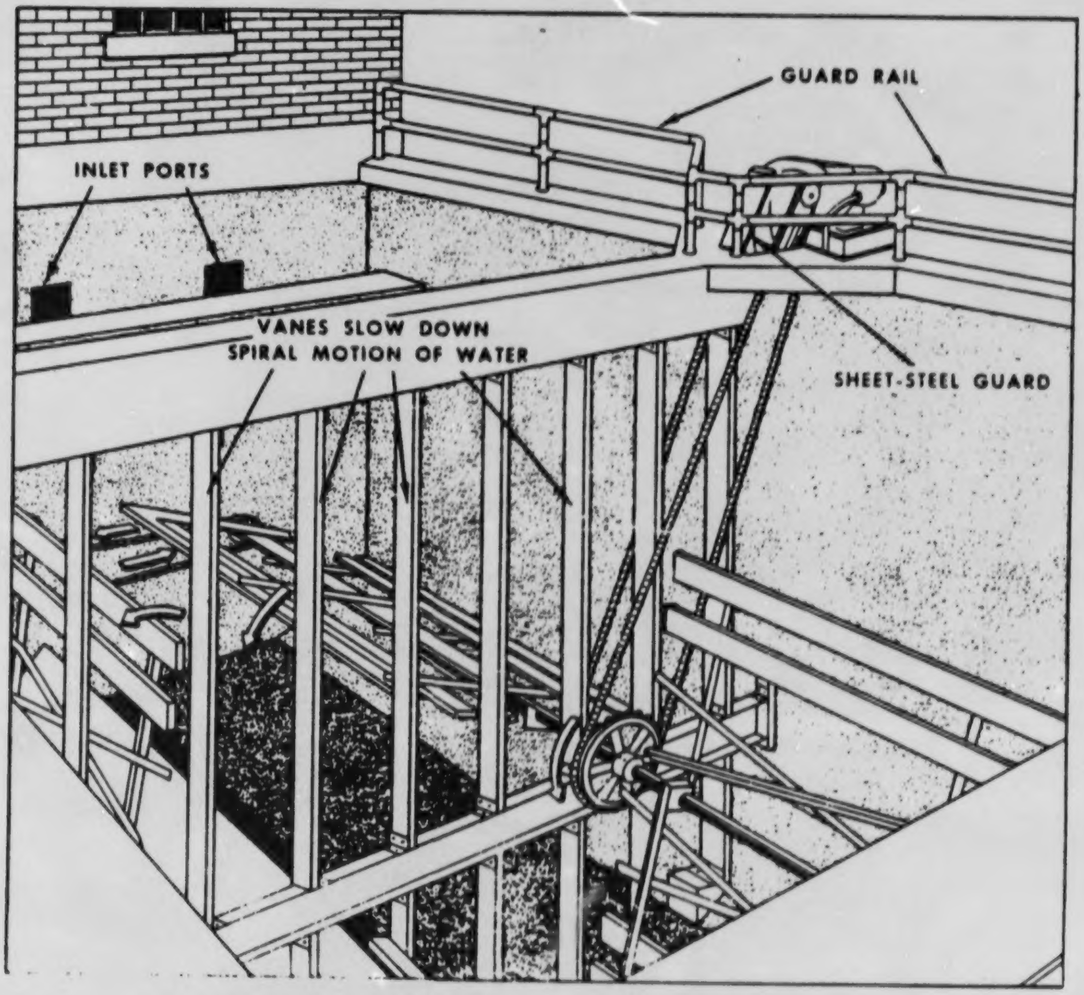


Figure 3. Rotary Flocculating Equipment

Settling Tank (Basin)

The main items in the operation of settling basins are (1) control of quantity of water flowing through the basin, (2) removal of sludge from the basin, and (3) cleaning the basins.

(1) Controlling the quantity of water flowing through the settling basin is accomplished by the use of plant metering devices or by periodic checking of the discharge rate of the raw water pumps. In cases where the raw water enters the plant by gravity flow, an orifice plate, venturi tube, or other type of meter, and a control valve should be installed so the flow can be controlled.

(2) Sludge removal from settling basins may be either intermittent or continuous. For settling basins not equipped for continuous sludge removal, it is necessary that an adequate number of drain valves properly spaced over the bottom of the tank should be provided. These valves are opened periodically and the sludge removed by gravity drainage. Continuous removal of sludge has been found to be more satisfactory and efficient, particularly where there is a considerable quantity of sludge to be removed. For round and square settling basins (figures 4 and 5) a spiral type rake is installed in the bottom of the tank, which rotates and moves the sludge to the center of the tank where the sludge drain is located. The bottom of the tank is usually sloped towards the center to move the sludge toward the drain. For rectangular basins (figure 5), scrapers are provided so they will drage sludge longitudinally along the floor of the basin, carrying the sludge to the sludge hopper. The sludge hopper is located at the end of the basin. Some of the sludge may be returned to the influent line. By doing this it will aid in coagulation and increase the settling rate.

(3) Generally, sedimentation basins are cleaned at three-month intervals or whenever an odor indicates that septic sludge conditions are developing. The area or climate will also determine when the basin will be cleaned.

Pumps

Pumps may be required at Air Force installations to pump water from a lake, reservoir, well, or river to a water treatment plant. After treatment, additional pumping may be required to force the water into the main and storage facilities. In the distribution system booster pumps may be needed to increase pressure. Standby or emergency pumps ordinarily are needed for operation during breakdown, power outage, or to satisfy fire demands

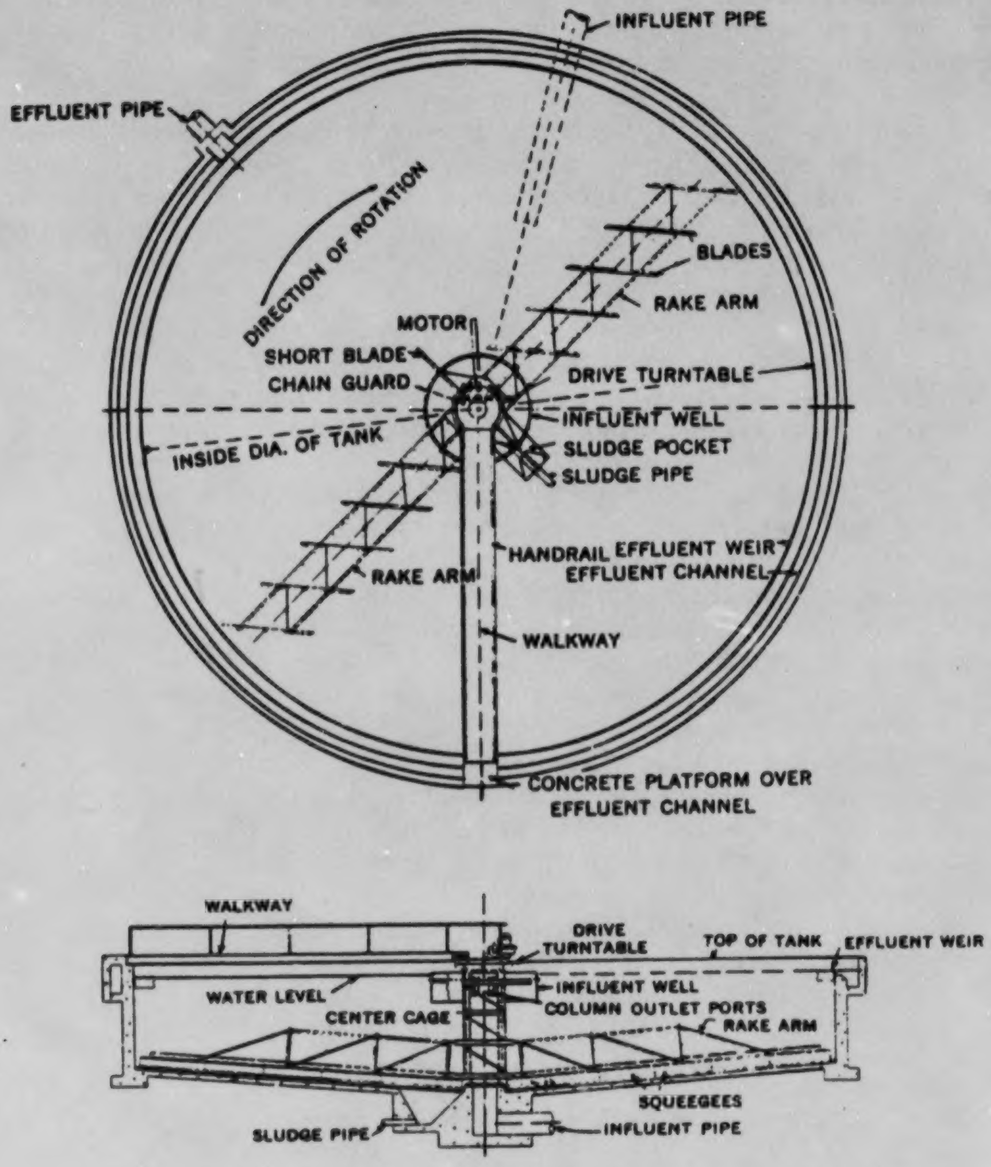

INFLUENT PIPE
EFFLUENT PIPE
DIRECTION OF ROTATION
BLADES
RAKE ARM
MOTOR
SHORT BLADE
CHAIN GUARD
DRIVE TURNTABLE
INFLUENT WELL
INSIDE DIA. OF TANK
SLUDGE POCKET
SLUDGE PIPE
HANDRAIL
EFFLUENT WEIR
EFFLUENT CHANNEL
RAKE ARM
WALKWAY
CONCRETE PLATFORM OVER EFFLUENT CHANNEL
WALKWAY
DRIVE TURNTABLE
TOP OF TANK
EFFLUENT WEIR
WATER LEVEL
INFLUENT WELL
COLUMN OUTLET PORTS
CENTER CAGE
RAKE ARM
SQUEEGEES
SLUDGE PIPE
INFLUENT PIPE

Figure 4. Circular Settling Basin

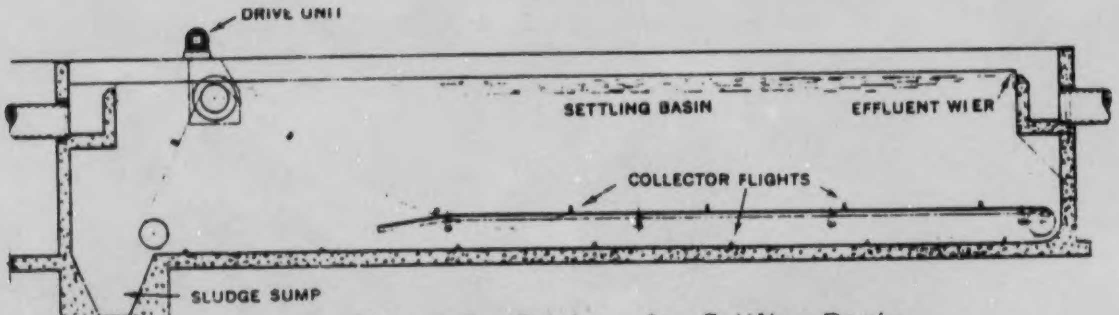

DRIVE UNIT
SETTLING BASIN
EFFLUENT WIER
COLLECTOR FLIGHTS
SLUDGE SUMP

Figure 5. Rectangular Settling Basin

Clearwell

It is desirable to operate filters at as uniform a rate as possible. Therefore, clearwells are built to provide a reservoir of filtered water to meet fluctuations in demands, and allow for contact holding time. They are also used to provide water for filter washing. They must be protected against contamination or pollution.

Filters

Water from the sedimentation basins is brought into the filters as the next step in the purification process. This water contains very finely divided suspended matter such as minute particles of floc, clay, and mud that have not combined into one body and bacteria and microscopic organisms that have not been removed by sedimentation. The purpose of the filter is to remove this suspended matter and give the water a clear, sparkling and attractive appearance.

Storage reservoir

The normal water demand in a community or installation varies considerably between night and day and for different days of the week. In addition, the fire demand may have to met at any time. These problems are met by providing storage capacity in the distribution system. During low demand periods, water is placed in storage for use during periods when the demand exceeds the capacity of the source, supply lines, treatment plant or pumps. Storage also enables water to be supplied during emergency conditions resulting from fires, power failure, breakdown of supply pumps, failure of supply mains, flooding, and other conditions that result from natural causes, accidents, or enemy action. Water may be stored in ground tanks or elevated tanks. Reservoirs or storage tanks higher than the distribution system, or the portion they serve, maintain the desired pressure in the system. Live storage is preferred, over dead storage. This is where the water is fed into the tank, and to the consumer and replaced constantly in the tank.

OPERATING PRINCIPLES

Mechanical Process

Sedimentation (plain). This is the process of removing or reducing the amount of mud, clay, or silt entering the water plant. It is done by, or in the raw water reservoirs or other holding areas. It is simply the slowing down of the water to give the water time to settle.

Screening. This is the process of removing or keeping large objects from reaching the plant. It removes items such as sticks, large stones, tin cans, or other such material. It will also keep some fish, and other aquatic life from entering the plant. Screens are also used in wells; these keep stones and gravel out of the pumping system.

Aerators. This is also a mechanical process, used in treating water. It has been covered earlier in this study guide.

Filtration. This process removes suspended matter and gives the water a clear, sparkling and attractive appearance. It has been discussed in another area of this guide, and will be discussed later in the course in detail.

Distillation. This process is used to treat salt or brackish water. It will also be covered later in the course.

Chemical Process

This is the addition of chemicals, or the use of chemicals to treat water. These will be referred to throughout this block of instruction.

SUMMARY

Aeration is exposing the water to air to reduce the gases. The rapid mixer is used to mix the chemicals and water together so it will react and form a floc. The water than passes on to the flocculator where the floc is built so it will settle out in the settling chamber. The filters then remove any fine suspended particles of floc or leaves, etc., that may have entered the water.

The water is moved through some plants by gravity and others by pumps. It is then stored or used by the personnel. While the water is waiting to enter the plant, the treatment process has started to take place. When it enters the plant, chemicals are added for further treatment. It is then disinfected and put to use.

QUESTIONS

1. What is the purpose of an aerator?

2. What is the purpose of a rapid mixer?

3. What will excessive agitation do to floc?

4. What is the usual contact time in a flocculator?

5. What are the three items of operation in a settling tank?

6. How is sludge removed from settling tanks?

7. Why is sludge returned to the raw water influent line?

8. Why are pumps needed for Air Force water treatment?

9. What is the purpose of a clearwell?

10. What is the first treatment in the mechanical process?

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CLARIFICATION OF WATER

OBJECTIVES

The objective of this study guide is to acquaint you with the procedures used in removing the impurities in water that are both visible and invisible and the treatments used to keep water pure and clean until its final use.

INTRODUCTION

You have filled a glass of water from a water faucet and found small floating items or perhaps sand in the water. The water was probably safe for drinking but was not suitable for other uses such as adding to batteries. During this block of instruction you will learn how to treat raw water so it can be used for most any purpose.

Information on this subject will be covered in the following main topics:

CLARIFICATION

MINERALS CONTRIBUTING TO HARDNESS

PROCESSES USED TO REDUCE HARDNESS

CHEMICAL ADDITIVES USED TO REDUCE HARDNESS

CHEMICALS USED TO CONTROL ALGAE

CLARIFICATION

Clarification means making water clear by removing the contamination. Raw water from wells is usually clear and normally needs only a germ killing chemical added. Raw water from lakes, streams, and rivers is usually muddy and contains animal and vegetable matter. This dirty water certainly needs filtering; however, there may be a cheaper and more efficient treatment than filtering.

Sedimentation

Sedimentation is a process of removing mud, sand, silt,and other solids that will settle to the bottom if the flow of water is slow enough. Many cities pump water from a river and place it in a settling lake. On the other side of the lake the water is almost clear because much of the mud and silt has settled out.

Sedimentation may be carried out in basins, tanks, reservoirs, or ponds. The length of time used in sedimentation may vary from a few hours to over a month. It depends on tank size and rate of water usage and the size of the particles settling out.

In smaller tanks and basins a series of fences or baffles can be constructed so the flow of water has to weave back and forth from side to side which greatly increases the distance the water has to flow to reach the other end. Naturally this zigzag flow has to be very slow to allow sediment to settle to the bottom.

Coagulation

After water has cleared by sedimentation, it still contains a lot of very small particles that are too small to settle out. The water may still be murky or tan in color.

At this point a chemical is added to the dirty water, and a strange thing happens. Small white clouds begin to form in the water. These clouds are called "floc." This floc is sticky and the small dirty particles in the water begin to stick to it. Soon the little clouds are so full of dirt that they settle to the bottom and new clouds are formed.

Slow mixing of the water will insure that all the silt will be trapped by the floc. Now the water is clear on the surface with all the silt at the bottom. The surface water can be drawn off for further treatment, and the silt on the bottom can be pumped out to a drying bed and used as dirt fill.

Chemicals Used in Coagulation

The chemicals commonly used in coagulation or making floc fall into two primary groups - alum coagulants and ferric coagulants.

ALUM COAGULANTS. Filter alum or aluminum sulfate is quite soluble in water. It is fed either in dry powder form or in solution. A chemical reaction in the water causes the aluminum to form aluminum hydroxide. Aluminum hydroxide is the floc that suddenly begins to occur in the water.

Black alum is alum containing activated carbon. It reacts the same as filter alum; however, the carbon is used when taste and odor are problems.

Ammonium alum is sometimes used when a slower dissolving coagulant is needed. The ammonia released also aids the disinfecting qualities of chlorine.

Sodium aluminate is a good coagulant that is generally used with lime for special treatment processes such as softening and color removal.

FERRIC COAGULANTS. Ferric sulfate, commonly known as copperas, is a coagulant. When using copperas, lime must usually be added because the alkalinity and pH values of neutral water are generally too low to react with copperas to form a floc. Water pH should be above 9 for good reaction. Copperas is very soluble and a solution is easily made by stirring one part ferric sulfate with two parts of water.

Chlorinated copperas, a combination of lime and chlorine with ferrous sulfate, will react to form an excellent floc. Chlorinated copperas can also be used for color removal. You will see this process on one of your field trips in this course.

Ferric chloride has been successfully used over a wide range of pH values and is effective in treating soft, colored waters. Three commercial forms of ferric chloride are available: they are liquid, crystalline, and anhydrous.

Ferrous sulfate, as a coagulant, is similar to ferric chloride, but goes into solution slowly in cold water.

Jar Test

It is not always easy to mathematically determine the correct dosage for coagulants. Three things must be considered when developing a floc; amount of coagulant needed, pH adjustment of the water, and the need of coagulant aids such as clay, powdered marble, or activated silica to add weight for settling.

Floc forms fastest and is heaviest at a definite pH value. Because this pH value changes with the impurities in water, it is necessary to determine it by the jar test. For the procedures in performing the jar test see 563X0 Career Ladder, Lab. Manual.

Chemicals Used to Adjust pH

The chemicals commonly used to adjust pH as an aid in coagulation are soda ash, pulverized limestone, and lime.

Soda ash (sodium carbonate) is highly soluble in water. This chemical is used when the water does not contain enough natural alkalinity to react with the coagulant. It is obtained as a commercial powder and will dissolve more slowly than ammonium alum.

Pulverized limestone is soluble only at low pH. The excess undissolved limestone serves to weigh the floc for more rapid settling. Lime is obtained as quicklime (calcium oxide) or as slaked lime (calcium hydroxide). It is used not only to provide alkalinity, but to soften water.

MINERALS CONTRIBUTING TO HARDNESS

The principle of precipitation has been previously mentioned in processes of coagulation and flocculation. It was pointed out that upon addition of a coagulant, such as aluminum sulfate to water containing alkalinity, a chemical reaction occurred between the two to form a jelly-like substance called "floc," and that this floc is an insoluble hydroxide or precipitate. The principle of chemical precipitation can be further used on waters containing excessive amounts of dissolved minerals. The most common types of dissolved minerals in water are calcium and magnesium. Removal of these minerals is known as water softening.

Hard water may be potable, but it is objectionable because it deposits scale in pipes and boilers, leaves stains on glassware and kitchen utensils, and requires excessive amounts of soap to form lather. The hardness of water can be judged from the amount of soap used to form lather. Hardness results from the presence of calcium and magnesium compounds in solution in the water. Amount of hardness is sometimes rated as shown below.

Over 200 ppm	very hard
100 - 200 ppm	hard
50 - 100 ppm	moderately hard
below 50 ppm	soft
below 15 ppm	very soft

Softening of hard water is achieved by changing the calcium and magnesium compounds from a soluble to an insoluble form and then removing the insoluble compounds by sedimentation and filtration.

The most common process of softening by precipitation is known as the lime-soda process. Lime-soda process plants are essentially the same as water filtration plants. Lime and soda ash are added to raw water, and the softening reaction occurs during mixing and flocculation; the precipitated calcium and magnesium are removed during sedimentation. If raw water has a high turbidity, the turbidity is partially removed by plain sedimentation prior to the softening process.

Hardness is generally classified as carbonate or noncarbonate hardness, depending on the chemical compounds that cause it.

Carbonate Hardness

Carbonate hardness, referred to as temporary hardness, is caused by calcium or magnesium bicarbonates in the water. They form when carbon dioxide combines with water to form a mild acid which, in turn, combines with calcium and magnesium carbonate in the surrounding soil. The carbonate is insoluble; the bicarbonate which is formed dissolves in the water.

Noncarbonate Hardness

Noncarbonate hardness, referred to as permanent hardness, is caused by:

(1) Calcium and magnesium sulfate
(2) Calcium and magnesium chloride
(3) Calcium and magnesium nitrate

NOTE: Iron in aluminum compounds also produces hardness, but usually is present in such small quantities that it is not generally associated with hardness. Water softening processes remove iron as well as calcium and magnesium salts.

PROCESSES USED TO REDUCE HARDNESS

Lime-Soda Processes

Water is softened by various methods such as ion exchange units or zeolite units. Another method which employs the addition of lime and soda ash to the water is used to remove both carbonate and noncarbonate hardness. Water is softened by removing compounds of calcium, magnesium, iron, and manganese by chemical means. The calcium and magnesium bicarbonate are called temporary (carbonate) hardness because they can be removed by boiling. The compounds that cannot be removed by boiling are the sulphates, and the chlorides and nitrates of calcium and magnesium. The presence of these compounds is called permanent (noncarbonate) hardness.

SOFTENING REACTION

CaO (calcium oxide) is added to water forming calcium hydroxide.

CaO	+	H_2O	$\longrightarrow$	$Ca(OH)_2$
Calcium Oxide		Water		Calcium Hydroxide

When lime is added to water containing carbonate (temporary hardness), the calcium hydroxide reacts with calcium and magnesium bicarbonates to form less soluble carbonates and hydroxides that precipitate out, leaving the water free of the substances causing carbonate hardness.

$Ca(HCO_3)_2$	+	$Ca(OH)_2$	$\longrightarrow$	$2CaCO_3$	+	$2H_2O$		
Calcium Bicarbonate		Calcium hydroxide		Calcium carbonate precipitate		Water		
$Mg(HCO_3)_2$	+	$2Ca(OH)_2$	$\longrightarrow$	$Mg(OH)_2$	+	$2CaCO_3$	+	$2H_2O$
Magnesium bicarbonate		Calcium hydroxide		Magnesium hydroxide precipitate		Calcium carbonate precipitate		water

A similar chemical reaction occurs when slaked or hydrated lime is used. In the lime-soda process, noncarbonate (permanent) hardness is removed from the water by use of soda ash Na_2CO_3 (sodium carbonate). When soda ash is added to water containing noncarbonate hardness, the following chemical reactions take place:

$CaSO_4$	+	Na_2CO_3	$\longrightarrow$	$CaCO_3$	+	Na_2SO_4
Calcium sulfate		Sodium carbonate		Calcium carbonate precipitate		Sodium sulfate
$CaCl_2$	+	Na_2CO_3	$\longrightarrow$	$CaCO_3$	+	$2NaCl$
Calcium chloride		Sodium carbonate		Calcium carbonate precipitate		Sodium chloride
$Ca(NO_3)_2$	+	Na_2CO_3	$\longrightarrow$	$CaCO_3$	+	$2NaNO_3$
Calcium nitrate		Sodium carbonate		Calcium carbonate precipitate		Sodium nitrate

Soda ash reacts with sulfates, chlorides, and nitrates of calcium to form insoluble precipitates. If the water contains both carbonate and noncarbonate hardness, as is usually the case, both lime and soda are used.

Determination of Dosage

Quantitative analysis of the water is necessary for determination of required dosage of lime and soda ash.

It is well to check the calculations for lime and soda ash requirements by actually adding the calculated dosage to small measured quantities of the water to be treated. The following procedures may be used.

1. Prepare a standard lime suspension by adding ten grams of lime to one liter of boiled and cooled distilled water. If quick lime is used, shake it with just enough water to make a boiling solution, then dilute to one liter. A standard solution of soda ash is prepared in the same way. Adding one ml of the standard solution to one liter of water gives a dosage of ten ppm.

2. Place one liter of water to be treated in a beaker or jar and add calculated quantities of lime and soda ash needed to soften it. Stir gently for 30 minutes and allow to settle until liquid becomes fairly clear, usually 10 to 15 minutes.

3. Siphon off about half the clear solution, warm to about 120°F (49°C) and filter through filter paper.

4. Analyze filtrate for alkalinity in accordance with standard laboratory test procedure.

In the operation of a softening plant, it is customary to use lime in excess of computed needs to the extent of 10 to 50 ppm. This is then removed by recarbonization. After recarbonization and filtration, the water should have an alkalinity of approximately 35 ppm.

The quantity of noncarbonate hardness allowed to remain in the water is regulated by decreasing soda ash feed in accordance with the total hardness desired. If the total hardness in the softened water is to be 85 ppm and the alkalinity 35 ppm, it is then necessary to remove all but 50 ppm of noncarbonate hardness.

Chemical Feeding

Continuous softening requires application of chemicals in proportion to the rate of flow of water through the treating units. If the flow is constant over definite periods of time, the chemicals can be fed through constant-feed machines. If the flow is variable, proportioning devices in which chemicals are fed in suspension or solution are used.

Soda ash dissolves easily in water forming a clear stable solution. After preparation, the solution needs no further agitation and can be added directly to the water through a proportioning device.

Lime, being only slightly soluble in water, forms a suspension known as milk of lime. Because suspended matter tends to settle, continuous agitation is necessary to keep the mixture uniform. Therefore, devices for feeding lime usually have mechanical agitators. Flow through feedlines must be fast enough to prevent lime from settling and clogging the lines. Long lines should be avoided or should be easily replaceable.

They should have pressure connections for flushing. Rubber hose or open troughs are frequently used for this purpose.

Some plants feed lime and soda ash through one proportioning device. Chemicals are mixed in the proper proportions with water and introduced as a thin slurry. This method is satisfactory where the composition of raw water is constant or does not change rapidly.

High Rate Softening Devices

Newer developments in softening include high rate equipment such as the precipitator, accelerator, hydrotreater, and spiractor. The precipitator, accelerator, and hydrotreater are also used as combined flocculation and sedimentation units without softening. When these units are operated before filtration to treat surface water with low suspended solids and low alkalinity, it may be necessary to add lime or clay to add weight and prevent rising floc. Wide fluctuation in flow, solids content, and temperature always cause operating problems which can best be corrected individually.

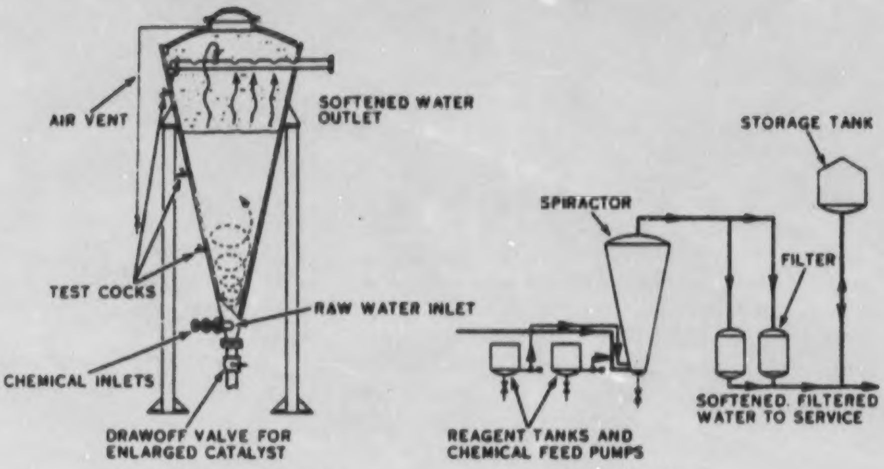
The accelerator, precipitator, and hydrotreater operate on essentially the same principles and the operation of the accelerator.

The spiractor (Figure 1) consists of a cone-shaped tank in which the lime-soda softening reactions take place in the presence of a suspended bed of granular calcium carbonate which acts as a catalyst. Hard water and chemicals enter the bottom of the cone where they mix immediately and rise through the granular bed with a swirling motion. The upward velocity keeps the granular material in suspension. As the water rises, velocity decreases to a point where material is no longer in suspension. The contact time, 8 to 10 minutes, is enough to complete softening reactions. Softened water is drawn off from the top of the cone. The precipitated hardness particles attach themselves to the calcium carbonate granules during the process, increasing the bulk of the granules in the unit. However, the level of the unit is kept down to the desired point by withdrawing the largest particles from the bottom. New catalyst material must be added periodically. The softened water is usually filtered through a sand filter to remove the remaining turbidity. Advantages of the equipment are its small size, low installation cost, rapid treatment, and lack of moving parts and pumping equipment. In addition, the precipitated hardness is withdrawn as sand-like granules, which are much easier to dispose of than the watery slime from the normal lime-soda process. The unit is most effective when hardness is predominantly calcium; there is less than 17 ppm magnesium hardness; water temperature is about 50° F.; and turbidity is less than 5 ppm.

Iron and Manganese Removal

When dissolved iron exceeds 0.3 ppm it causes an unpleasant taste and stains plumbing fixtures. If it goes over 2.0 ppm nobody likes to use it.

Iron is rarely found in surface waters but is often found in well water. If the dissolved iron does not exceed 2 to 3 ppm, staining of kitchen and bathroom fixtures can be prevented by treating with polyphosphate. Above 3 ppm iron removal treatment is necessary.


AIR VENT
SOFTENED WATER OUTLET
TEST COCKS
RAW WATER INLET
CHEMICAL INLETS
DRAWOFF VALVE FOR ENLARGED CATALYST
STORAGE TANK
SPIRACTOR
FILTER
REAGENT TANKS AND CHEMICAL FEED PUMPS
SOFTENED. FILTERED WATER TO SERVICE

SECTION OF SPIRACTOR

SYSTEM

Figure 1. Spiractor Softener

Aeration units are most commonly used to remove iron. Any method that can get air in the water will do. Some cities use a water fountain effect while others use a wooden tower with open mesh slats in it.

The object of aeration is to get oxygen to combine with the dissolved iron and form an iron compound that is not soluble in water. When the iron compound is no longer soluble it will come out of solution and can be caught up by flocculation then filtered out.

An added benefit of aeration is an improvement in taste and odor.

Accelator

This cold lime-soda water softener is in use at some of the missile sites and at some of the Air Force bases. Since it has the capacity of softening large quantities of hard water containing calcium and magnesium salts, this section will cover the common types of cold lime-soda softeners, operation of the accelator, and the theory of operation.

There are four basic types of cold lime-soda softeners, namely: (1) the sludge-blanket type, (2) continuous sedimentation type, (3) the "catalyst type," and (4) the intermittent or batch-process type. The first three are continuous types; that is, the water is treated as it is flowing through the equipment. The fourth type is, as its name indicates, one in which the flow of water is not continuous but intermittent, as the water is treated in separate batches. Of these, the sludge-blanket type, owing to its higher efficiency, short detention period, and smaller space requirements, is rapidly displacing the conventional type for industrial use. It is also widely used in the municipal field, but some state boards of health prefer longer detention periods than the customary one-hour detention period in the sludge-blanket type. This continuous sedimentation type is an older type. The catalyst type produces a granular type of sludge which can be handled readily and which drains and dries rapidly.

Sludge Blanket Type

This type differs from the sedimentation type in that the treated water is filtered upwardly through a suspended sludge blanket composed of previously formed precipitates. There are several distinct advantages obtained by this procedure. First, the upward filtration through the suspended sludge blanket results in the complete solution and use of the added lime. Second, the close contact of the treated water with a large mass of the sludge blanket prevents supersaturation. Third, the upward filtration in the sludge blanket results in the production of water which is clear enough without filtration for many industrial applications. Fourth, the detention period is much less for this type.

Figure 2 is a sketch of an accelator. In size, the vertical softeners may range from capacities of a few thousand to 10,000,000 gallons per day. Note that the outer chamber consists of a smaller conical or pyramidal section with its base more narrow than the top side. The raw water and the treating chemicals are introduced into the top of the inner chamber where they are thoroughly mixed by means of a centrally located mechanical agitator which is motor driven.

The chemical feeders used may be either of the wet or dry type, the latter type generally being employed only with the larger sizes of units. In the wet type of feeder, the hydrated or slaked lime is fed largely in the form of a suspension, usually of about a 5 percent concentration. Where soda ash is also required with the wet type of feeder, it is usually dissolved in and fed with the lime suspension instead of being fed separately. The coagulant is dissolved in and fed from a separate chemical feeder. When dry feeders are employed, separate feeders are used for the lime, the soda ash, and the coagulant.

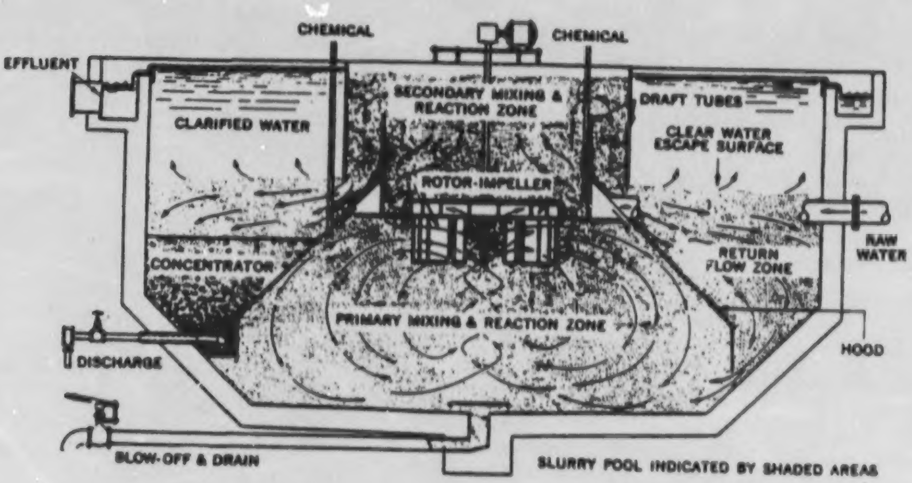

CHEMICAL
CHEMICAL
EFFLUENT
SECONDARY MIXING & REACTION ZONE
DRAFT TUBES
CLARIFIED WATER
CLEAR WATER ESCAPE SURFACE
ROTOR-IMPELLER
RAW WATER
RETURN FLOW ZONE
CONCENTRATOR
PRIMARY MIXING & REACTION ZONE
HOOD
DISCHARGE
BLOW-OFF & DRAIN
SLURRY POOL INDICATED BY SHADED AREAS

Figure 2. The Accelator

The mechanical agitator consists of a series of paddles mounted on a vertical shaft, driven by a motor acting through a reducing gear. As the hardness in the water reacts with the added chemicals, the precipitates are produced which are kept in suspension by the agitator. The treated water, with its suspended precipitates, flows slowly to the bottom of the inner chamber and there, emerging from a series of openings, it reverses its flow and slowly rises in the outer chamber. Stilling baffles are sometimes used at the bottom to stop the rotary motion from being carried up in the outer chamber.

As the treated water rises in the outer chamber, its vertical velocity in the lower part of the chamber is sufficient to keep the precipitates in suspension. Owing to its design, the cross-sectional area of the outer chamber constantly increases while passing from the bottom to the top. Consequently, the vertical velocity of the treated water constantly decreases during its passage through the outer chamber. Finally, a level is reached where, with a given volume of suspended sludge and for a given flow rate, it is unable to expand the sludge blanket further upward. This marks the upward level of the sludge blanket, and, in practice, there is a clear line of demarcation between the upper level of the sludge blanket and the clear water rising above it which is collected by the collector system and then passes either directly to service or to the filters and then to service.

This upper sludge level is kept by bleeding off sludge at the same rate as that at which new sludge is being formed. This bleed-off can be done automatically. The bleeding-off operation is usually performed through an integral sludge concentrator. Increasing the flow rate will increase the height of the sludge blanket, and lowering the flow rate will decrease it. If the flow is lowered, the blanket contracts, but since the cross-sectional area decreases downwardly, the blanket is kept "alive" and functions just as efficiently. In general, the range over which types of equipment such as this will function satisfactorily is from 20 percent of the rated capacity, as the low limit, to about 110 percent, as the high limit.

Clarifier

The clarifier (Figure 3) removes suspended matter and softens the water by the lime soda process. Water enters the clarifier at the top of the inner chamber and is flash mixed with the alkali and coagulant solutions. The alkali reacts to precipitate the hardness, and regulate the pH for best coagulation. The coagulant reacts with the added alkalinity to form a floc which tends to increase in size and settle towards the bottom. Slowly revolving agitator blades at the bottom and at the center of the inner chamber gently mix the floc and the water. This operation further increases the floc size as particles of suspended matter and precipitated hardness are caught by the floc. Clear water rises in the outer chamber and the heavy floc tends to remain in the lower portion of the outer chamber. Clear water flows through a distributor in the top of the outer chamber into a clearwell. A pump pumps the clear water from the clearwell. Over a period of time floc tends to build up in the outer chamber. The desludging timer should be adjusted to maintain the floc blanket just below the third sampling cock from the bottom. If the floc is very slow settling it may be necessary to blow down more frequently to prevent the carry over of floc into the clearwell.

Proper operation of the clarifier is dependent upon the following factors:

a. Raw water quality
b. Water temperature
c. Coagulant and alkali feed rates
d. Type of coagulant and alkali used
e. Raw waterflow rate

The alkali used must precipitate enough of the hardness to reduce the total hardness of the clarifier effluent to 200 to 300 ppm. Three possible alkalies, (soda ash, lime soda, or caustic soda) may be used. Soda ash removes the noncarbonate hardness. The lime and caustic soda remove the carbonate hardness. Soda ash, which will remove additional noncarbonate hardness, is formed also by the reaction of caustic soda with the carbonate hardness. Because of the acid treatment before the degasifier, the water entering the clarifier has essentially no carbonate hardness. The majority of the alkali solution must be soda ash. A certain amount of carbonate hardness will form when the soda ash is added. For this reason either lime or caustic soda must be used to precipitate the carbonate hardness. The optimum alkali solution is the solution which will allow the reduction of the hardness to 200 to 300 ppm as $CaCO_3$ and still prevent the rise of the effluent pH above the 9.0 to 9.5 range. It is in this pH range that the solubility of calcium carbonate is lowest and maximum softening will result.

The coagulant used and the coagulant feed rate will be largely determined by the pH of the clarifier water, jar test results, and chemical cost. There are several coagulants that may be used. Some of these are alum (aluminum sulfate), ferrous sulfate, ferric sulfate or ferric chloride. Alum generally coagulates best in the pH range of 5.5 to 8.0. Ferrous sulfate coagulates best in the pH range of 8.5 to 11.0. The ferric coagulants coagulate over a wide pH range of 4.0 to 11.0.

Clarifier Controls

The agitator drive on the clarifier is controlled by a manual motor starter. Because the agitator drive must be operated continuously (even when the well pump is not operating), it is not controlled by the relay in the well pump controls. The blowdown timer is controlled by contacts in the well pump controls. These contacts close to energize a timer five seconds after the well pump starts. As the timer runs, it periodically closes contacts to energize the blowdown solenoid valve. The timer is adjusted to blow down the clarifier often enough to prevent the carryover of floc into the clearwell.

Electrical controls for the pump are set as follows: The selector switch is placed in an automatic position. The manual motor starter is placed in the ON position. Then the results are as indicated. The pump motor is energized if the contacts on the float switch are closed. The float switch is located in the clarifier clearwell and controls the pump to prevent the pump from pumping the clearwell dry. The pump may be started independent of the float switch, by positioning the selector switch to the hand position. This type operation is only for clarifiers shown in Figure 3.

CHEMICAL ADDITIVES USED TO REDUCE HARDNESS

The lime soda softening process often results in formation of soluble carbonates of magnesium and high alkalinity of softened water. Methods of overcoming this limitation are discussed below.

1. Excess Lime Treatment

   In the excess lime treatment, 35 to 50 ppm excess lime or more is added to precipitate the magnesium almost completely. Excess calcium is then precipitated with soda ash. Soda ash dosage is the amount required to combine with the noncarbonate hardness of water and excess lime. If the water is recarbonated after filtration to a pH of 8.0, it will be palatable and will have a hardness of about 30 ppm.

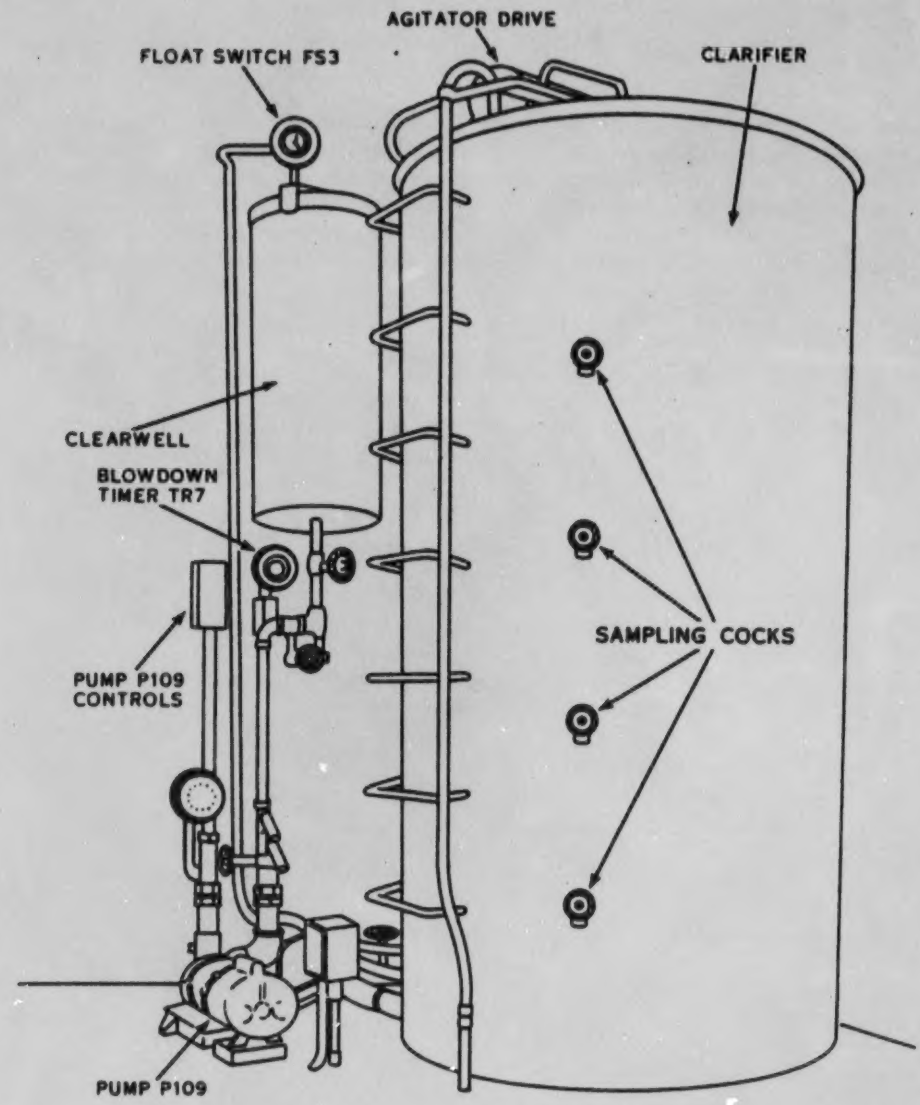

AGITATOR DRIVE
FLOAT SWITCH FS3
CLARIFIER
CLEARWELL
BLOWDOWN TIMER TR7
SAMPLING COCKS
PUMP P109 CONTROLS
PUMP P109

Figure 5. Clarifier Assembly

2. Split Treatment

   In water treatment plants which were not designed for softening, inadequacy of softening facilities can be overcome by split treatment. In this process, as large a portion of the raw water as possible is overtreated to obtain maximum reduction of hardness. The excess is then neutralized with raw water. Split treatment produces a greater hardness of a given quantity of raw water than does addition of the same quantity of chemicals to the total supply.

3. Excess Lime and Recarbonation

   Treatment with excess lime and recarbonation consists of the excess lime treatment and use of carbon dioxide to neutralize the excess lime. Carbonate hardness can be reduced by this method approximately to the solubility limit, 20 to 35 ppm hardness (depending on temperature). Calcium carbonate is least soluble at pH of 9. 3 to 9. 7.

4. Addition of Aluminum Compounds

   Aluminum compounds coagulate finely divided precipitates, thereby making their removal easier. Without aluminum treatment, longer periods are required for precipitates to coagulate and settle. Addition of aluminum compounds changes soluble magnesium salts to soluble magnesium aluminates which can be removed by settling or filtration.

5. Treatment with excess lime, recarbonation, and secondary flocculation is carried out as follows:

   a. Add excess lime and correct amount of soda ash to combine with noncarbonate hardness, mix and allow to settle.

   b. Neutralize excess lime with carbon dioxide gas.

   c. Mix with sludge produced by the water softening process or with a coagulant and allow to settle.

   d. Add carbon dioxide gas again and filter. This process decreases load on filters, lessens incrustation of filter sands, and produces a more nearly balanced and, therefore, more stable filtered water. It is especially adapted to treating and softening turbid water.

Dissolved Iron

Dissolved iron is effectively removed by lime or lime soda treatment for softening water. The high pH created by lime results in formation of a rapid settling ferric hydrate floc. Oxidizing chemicals such as chlorine or hypochlorites can be used to supply the necessary oxidation to convert iron to the insoluble form, although aeration prior to chemical addition usually is much more efficient and economical.

Where iron is easily oxidized by aeration, the following chemical additions hasten subsequent sedimentation (best dosage is determined by laboratory flocculation tests):

1. Lime and aluminum sulfate or ferric salts with 20 to 30 minute flocculation. Recarbonation should follow if the lime treatment has increased the pH sufficiently to throw water out of chemical balance.

2. Aluminum sulfate.

3. A pH of over 8.0 helps flocculate the iron hydrate and may, in case of high iron content, produce all the floc necessary to remove turbidity. Lime is used for this pH adjustment. This treatment is necessary in acid waters.

Where iron resists oxidation by aeration and sedimentation, sand filters act as contact beds and remove most of the remaining iron. The oxidizing is confined to the upper portion of the bed and results in coating the sand with iron oxide which has been found to be more active than clear sand for iron removal.

Manganese

Manganese, when present, is almost invariably associated with iron. Due to its chemical similarity to iron, it is removed by the same processes. However, manganese is not oxidized as readily as iron. This is shown by black manganese stains below the iron in sand filters.

1. Filter sand with a manganese dioxide coating aids in removing the manganese. Contact aerators are quite effective.

2. Since manganese is removed by coagulation only at a relatively high pH value, it is necessary to use a coagulant which has its optimum in a high range. Ferrous sulfate is usually used in a pH range above 9.0.

3. Oxidation of the manganese with chlorine followed by coagulation and pH control, sedimentation, and filtration usually gives satisfactory results.

4. Polyphosphates will hold manganese in solution provided the manganese does not exceed approximately 1 ppm. A weight ratio of about 2 ppm to 1 ppm of manganese is required.

Need for Stabilization

Production of an acceptable water does not end with disinfection, clarification, and filtration. Water furnished for consumption must neither scale nor corrode the distribution system. The processes of coagulation and softening previously described do not, as a rule, produce a water that will meet these requirements. The pH, alkalinity and hardness may be so low and the carbon dioxide (CO_2) so high that the water may corrode the piping system; or the pH and alkalinity may be so high that the calcium carbonate will scale mains, meters, and hot water heaters. To avoid these circumstances, water may be first supersaturated as to calcium carbonate content, in which condition a protective film against corrosion will deposit on pipe walls; then, an equilibrium point of the water is sought such that it will neither dissolve nor deposit calcium carbonate. Under these conditions a protective coating of calcium carbonate lining pipe walls will be undisturbed, thus preventing corrosion of the metal underneath, and progressive scaling will not occur.

The adjustment of pH and alkalinity of a water to a calcium carbonate saturation-equilibrium value is known as stabilization. The pH associated calcium carbonate equilibrium may either be calculated or determined by the calcium carbonate stability test. A formula developed by Langelier forms the basis of calculations for pH saturation values (Table 1). For routine chemical control the calcium carbonate stability test offers a simple and direct indication of the equilibrium of calcium carbonate in the water. A modification of the marble test, known as McLaughlin's "Marble Test" Graph, will be found useful in calculation of lime dosages for pH correction.

McLaughlin's "Marble Test" Graph

Set up a series of liter or gallon samples of the same water in a stirring machine. Determine alkalinity of the original water. Dose each with increasing amounts of lime solution to cover the whole range of probable treatment. Stir for one-half hour and settle for four hours. Accomplish the alkalinity test on each product and plot the change in alkalinity against the corresponding pH value. Such a plot is shown in Figure 4. The point of zero alkalinity change, that is, where the curve crosses the horizontal axis, marks the pH to which the water should be raised by lime treatment.

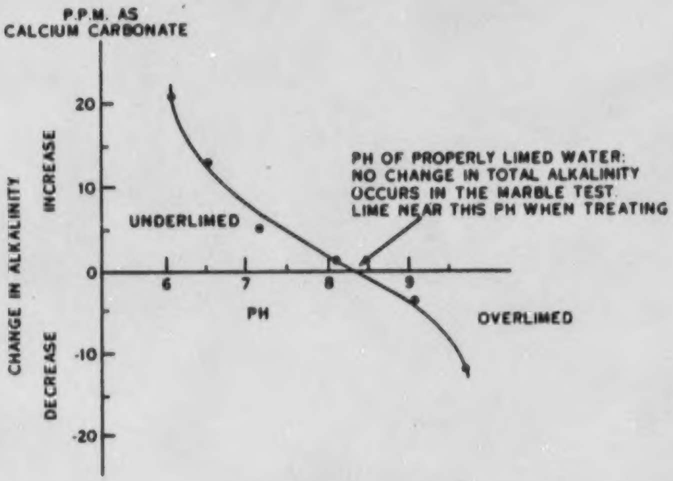


Figure 4. McLaughlin's Test Graph

Stabilization of Coagulated Waters

If an analysis of coagulated waters shows them to be undersaturated, the calcium carbonate content must be built up if red water troubles are to be avoided. This is usually done by the addition of lime (either hydrated or quick lime); or if the water contains calcium sulfate, soda ash may be added. (Soda ash reacts with calcium sulfate to produce calcium carbonate.) For example, it has been shown that waters containing sufficient natural alkalinity and pH adjustments of such waters are usually made with the addition of lime which raises the pH to the desired value as calculated by the tests previously mentioned. Hardness of the water is usually increased somewhat. Normally, the amount due to this cause is not great enough to be objectionable.

$CaCO_3$ SATURATION INDEX (LANGELIER INDEX)

(Based on the Langelier Formula Larson-Buswell Residue-Temperature Adjustments Arranged by Nordell)

1. $pH_s = (9.30 + A + B) - (C + D)$
   (Note: Values of A, B, C, & D are obtained from tables A, B, C, & D)
2. Saturation Index = $pH_s - pH$
   If index = 0, water is in chemical balance.
   If index is a plus quantity, scale forming tendencies are indicated.
   If index is a minus quantity, corrosive tendencies are indicated.

Example: To find the saturation index at 124°F of water which has the following characteristics: Total solids=400 ppm; calcium hardness as $CaCO_3$=240 ppm; alkalinity as $CaCO_3$=196 ppm, and pH of 7.2. Then

Total solids. . . . 400 ppm = 0.16 (from table A)
Temperature . . . 124° F = 1.53 (from table B)
Calcium hardness as $CaCO_3$ . . . . 240 ppm = 1.98 (from lower table C)
Alkalinity as $CaCO_3$. . . . . 196 ppm = 2.29 (from upper table D)

Substituting $pH = (9.30 + 0.16 + 1.53) - (1.98 + 2.29) = 6.72$ (or 6.7)
Saturation Index = 7.2 − 6.7 = −0.5

A
Total Solids in ppm

Ppm Total Solids	
50	.07
75	.08
100	.10
150	.11
200	.13
300	.14
400	.16
600	.18
800	.19
1000	.20

B
Temperatures in degrees Fahrenheit

	UNITS				
TENS	0	2	4	6	8
30		2.60	2.57	2.54	2.51
40	2.48	2.45	2.43	2.40	2.37
50	2.34	2.31	2.28	2.25	2.22
60	2.20	2.17	2.14	2.11	2.09
70	2.06	2.04	2.03	2.00	1.97
80	1.95	1.92	1.90	1.88	1.86
90	1.84	1.82	1.80	1.78	1.76
100	1.74	1.72	1.71	1.69	1.67
110	1.65	1.64	1.62	1.60	1.58
120	1.57	1.55	1.53	1.51	1.50
130	1.48	1.46	1.44	1.43	1.41
140	1.40	1.38	1.37	1.35	1.34
150	1.32	1.31	1.29	1.28	1.27
160	1.26	1.24	1.23	1.22	1.21
170	1.19	1.18	1.17	1.16	

C
Calcium hardness expressed as ppm $CaCO_3$
(For 3 to 209 ppm $CaCO_3$, use upper table)
(For 210 to 990 ppm $CaCO_3$, use lower table)

	UNITS									
TENS	0	1	2	3	4	5	6	7	8	9
0				0.08	0.20	0.30	0.38	0.45	0.51	0.56
10	0.60	0.64	0.68	0.72	0.75	0.78	0.81	0.83	0.86	0.88
20	0.90	0.92	0.94	0.96	0.98	1.00	1.02	1.03	1.05	1.06
30	1.08	1.09	1.11	1.12	1.13	1.15	1.16	1.17	1.18	1.19
40	1.20	1.21	1.23	1.24	1.25	1.26	1.26	1.27	1.28	1.29
50	1.30	1.31	1.32	1.33	1.34	1.34	1.35	1.36	1.37	1.37
60	1.38	1.39	1.39	1.40	1.41	1.42	1.42	1.43	1.43	1.44
70	1.45	1.45	1.46	1.47	1.47	1.48	1.48	1.49	1.49	1.50
80	1.51	1.51	1.52	1.52	1.53	1.53	1.54	1.54	1.55	1.55
90	1.56	1.56	1.57	1.57	1.58	1.58	1.58	1.59	1.59	1.60
100	1.60	1.61	1.61	1.61	1.62	1.62	1.63	1.63	1.64	1.64
110	1.64	1.65	1.65	1.66	1.66	1.66	1.67	1.67	1.67	1.68
120	1.68	1.68	1.69	1.69	1.70	1.70	1.70	1.71	1.71	1.71
130	1.72	1.72	1.72	1.73	1.73	1.73	1.74	1.74	1.74	1.75
140	1.75	1.75	1.75	1.76	1.76	1.76	1.77	1.77	1.77	1.78
150	1.78	1.78	1.78	1.79	1.79	1.79	1.80	1.80	1.80	1.80
160	1.81	1.81	1.81	1.81	1.82	1.82	1.82	1.82	1.83	1.83
170	1.83	1.84	1.84	1.84	1.84	1.85	1.85	1.85	1.85	1.85
180	1.86	1.86	1.86	1.86	1.87	1.87	1.87	1.87	1.88	1.88
190	1.88	1.88	1.89	1.89	1.89	1.89	1.89	1.90	1.90	1.90
200	1.90	1.91	1.91	1.91	1.91	1.91	1.92	1.92	1.92	1.92

	TENS									
HUNDREDS	0	10	20	30	40	50	60	70	80	90
200		1.92	1.94	1.96	1.98	2.00	2.02	2.03	2.05	2.06
300	2.08	2.09	2.11	2.12	2.13	2.15	2.16	2.17	2.18	2.19
400	2.20	2.21	2.23	2.24	2.25	2.26	2.26	2.27	2.28	2.29
500	2.30	2.31	2.32	2.33	2.34	2.34	2.35	2.36	2.37	2.37
600	2.38	2.39	2.39	2.40	2.41	2.42	2.42	2.43	2.43	2.44
700	2.45	2.45	2.46	2.47	2.47	2.48	2.48	2.49	2.49	2.50
800	2.51	2.51	2.52	2.52	2.53	2.53	2.54	2.54	2.55	2.55
900	2.56	2.56	2.57	2.57	2.58	2.58	2.58	2.59	2.59	2.60

D
Alkalinity expressed as ppm $CaCO_3$
(For 1 to 209 ppm $CaCO_3$, use upper table)
(For 210 to 990 ppm $CaCO_3$, use lower table

	UNITS									
TENS	0	1	2	3	4	5	6	7	8	9
0		0.00	0.30	0.48	0.60	0.70	0.78	0.85	0.90	0.95
10	1.00	1.04	1.08	1.11	1.15	1.18	1.20	1.23	1.26	1.29
20	1.30	1.32	1.34	1.36	1.38	1.40	1.42	1.43	1.45	1.46
30	1.48	1.49	1.51	1.52	1.53	1.54	1.56	1.57	1.58	1.59
40	1.60	1.61	1.62	1.63	1.64	1.65	1.66	1.67	1.68	1.69
50	1.70	1.71	1.72	1.72	1.73	1.74	1.75	1.76	1.76	1.77
60	1.78	1.79	1.79	1.80	1.81	1.81	1.82	1.83	1.83	1.84
70	1.85	1.85	1.86	1.86	1.87	1.88	1.88	1.89	1.89	1.90
80	1.90	1.91	1.91	1.92	1.92	1.93	1.93	1.94	1.94	1.95
90	1.95	1.96	1.96	1.97	1.97	1.98	1.98	1.99	1.99	2.00
100	2.00	2.00	2.01	2.01	2.02	2.02	2.03	2.03	2.03	2.04
110	2.04	2.05	2.05	2.05	2.06	2.06	2.06	2.07	2.07	2.08
120	2.08	2.08	2.09	2.09	2.09	2.10	2.10	2.10	2.11	2.11
130	2.11	2.12	2.12	2.12	2.13	2.13	2.13	2.14	2.14	2.14
140	2.15	2.15	2.15	2.16	2.16	2.16	2.16	2.17	2.17	2.17
150	2.18	2.18	2.18	2.18	2.19	2.19	2.19	2.20	2.20	2.20
160	2.20	2.21	2.21	2.21	2.21	2.22	2.22	2.23	2.23	2.23
170	2.23	2.23	2.23	2.24	2.24	2.24	2.24	2.25	2.25	2.25
180	2.26	2.26	2.26	2.26	2.26	2.27	2.27	2.27	2.27	2.28
190	2.28	2.28	2.28	2.29	2.29	2.29	2.29	2.29	2.30	2.30
200	2.30	2.30	2.30	2.31	2.31	2.31	2.31	2.32	2.32	2.32

	TENS									
HUNDREDS	0	10	20	30	40	50	60	70	80	90
200		2.32	2.34	2.36	2.38	2.40	2.42	2.43	2.45	2.46
300	2.28	2.49	2.51	2.52	2.53	2.54	2.56	2.57	2.58	2.59
400	2.60	2.61	2.62	2.63	2.64	2.65	2.66	2.67	2.68	2.69
500	2.70	2.71	2.72	2.72	2.73	2.74	2.75	2.76	2.76	2.77
600	2.78	2.79	2.79	2.80	2.81	2.81	2.82	2.83	2.83	2.84
700	2.85	2.85	2.86	2.86	2.87	2.88	2.88	2.89	2.89	2.90
800	2.90	2.91	2.91	2.92	2.92	2.93	2.93	2.94	2.94	2.95
900	2.95	2.96	2.96	2.97	2.97	2.98	2.98	2.99	2.99	3.00

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Table 1

Stabilization of Lime Softened Waters

Lime softened water may not be stable because of the high content of calcium and magnesium carbonates. If the excess is not removed, scale is deposited in the distribution system, hot water heaters, meters, and the like. Encrusting of filter sand and gravel is also experienced.

Lime softened water can be stabilized by recarbonating with carbon dioxide gas. After the water has passed through the settling basins but before it has reached the filter, carbon dioxide is diffused into the water through small openings in a grid system. The carbonic acid formed by the gas in solution neutralizes excess alkalinity in the water and converts slightly soluble excess lime and carbonates to highly soluble bicarbonates. Bicarbonates do not precipitate from water easily so scale formation is prevented. Excessive recarbonation can produce a corrosive water, if carbonic acid (free CO_2) remains after completion of the reaction.

Lime softened water can also be stabilized with sulphuric acid. Because calcium sulphate is formed by the reaction, close control of dosage is necessary to avoid formation of excess amounts of noncarbonate hardness. Base the dosage on laboratory scale treatment and alkalinity test.

Scale and Corrosion Control

Most of the scale formed in water systems is similar in appearance; however, there are several distinct types of scale. Among the most common are (1) pure mineral scale, (2) mixed scale and corrosion products, and (3) combination of minerals.

1. Pure mineral scale, such as $CaCO_3$ and $CaSO_4$. Calcium carbonate forms a loose sludge-like deposit that will crumble rather easily when dried. Calcium sulfate forms a hard adherent type of scale which is especially objectionable in boilers.

2. Mixed scale and corrosion products. Hot water pipes are often found containing layers of rust sandwiched in between layers of mineral scale.

3. Combinations of minerals cemented together by binders, such as silica. Such combinations will produce a hard "baked-on" type of scale on hot boiler surfaces.

Scale is an undesirable formation, having the following adverse effects:

1. Reduces the safety factors by clogging the safety valves and gauge lines.

2. Clogs pipes, thus reducing carrying capacity. Pipes should be cleaned, if possible, rather than replaced. Once the scale has been removed, a chemical treatment should be used to prevent new formation.

3. Reduces operating efficiency of heating and cooling systems by clogging coils, heat exchangers, and radiators.

4. Reduces rate of heat transfer in boilers.

5. Increases cost of operation by adding to cost of maintenance and replacement.

The treatment used to clarify water may result in a very clear sparkling product and yet be a heavy scale maker.

In the cold lime process of clarification, water is softened by chemical reaction. This reduces the scale forming hardness minerals thereby protecting the distribution system from severe scaling. Any process that will reduce hardness will reduce scale.

Scale can be formed by several different compounds but distribution lines are most commonly found to contain calcium carbonate and calcium sulfate.

Besides using softened water another method of preventing scale formation is the addition of polyphosphates. Polyphosphates will prevent the hardness minerals from coming out of solution to form the scale and also stop the chemical reaction of lime softening so it will not precipitate out in the distribution lines.

Corrosion or rust is always a problem in waterlines and can, if conditions are right, completely destroy a waterline in one year or less. Corrosion inside a water pipe is difficult to detect and major damage can occur before it is found.

When water has a low pH (below 7) corrosion can occur rapidly. The remedy is to raise the pH of the water by adding chemicals that will add alkalinity to the water such as sodium hydroxide (lye). If the water is treated in a lime-soda plant it also will cause the pH to rise above a corrosive level.

Many waterplants add small amounts of phosphate compounds to prevent pipeline corrosion. Phosphates will form a very thin film on the inside walls of pipes and so prevent moisture and oxygen from attacking the iron.

When water is to be used commercially, such as in boilers or cooling towers, then strong doses of corrosion preventatives can be added but domestic water must be only lightly treated and then only with chemicals that are not poisonous.

CHEMICALS USED TO CONTROL ALGAE

Presence of algae does not make water unsafe. However, uncontrolled algae growth frequently causes unpleasant tastes and odors and it may clog pipes and filter beds, thus lowering efficiency. Filter difficulties are generally caused by a small group of diatoms. Taste and odor problems are generally caused by a wide variety of algae, the type and intensity of the problem varying with the particular algae concerned. Algae growth occurs mainly in large open reservoirs, in sluggish streams, and in surface supplies. Sunlight is necessary for its existence.

(1) Copper Sulfate. Copper sulfate treatment is most effective if started early in the season before heavy algae concentration has formed. The treatment is repeated whenever algae growths reappear. If copper sulfate can be applied by solution feeder to water entering the reservoir, continuous application of lower concentrations can be used instead of intermittent treatment. This usually results in the most efficient control of algae growths. Copper sulfate treatment should be started when the algae count exceeds 20 organisms per millimeter of water, as measured by the centrifugal or Sedgewick-Rafter funnel methods or by microscopic examinations.

(a) The simplest, though not the best method, of applying copper sulfate is to tie a bag of copper sulfate crystals to a boat and cover the reservoir in a definite zigzag pattern.

(b) In reservoirs needing frequent treatment, the best method is to spray copper sulfate solution on the water surface from a spray unit mounted in a boat. Apply the solution evenly to avoid overdosing shallow areas.

(2) Chlorine. Chlorine may be applied as hypochlorite solution or chlorine gas. Hypochlorite is sprayed on the water from a boat-mounted spray unit. Gas is fed from a boat-mounted chlorinator through a submerged diffuser into the water. Either may be fed continuously when controlled dosage can be applied to water entering the reservoir.

(3) Activated Carbon. In large reservoirs and impounded supplies, activated carbon is applied by spray from a boat. In small basins, regular spraying and hand spreading can be used. In filtration plants carbon is usually added before coagulation. Suspended carbon carried to the filters is effective in removing odors, although shortening of filter runs may occur.

(4) Mechanical. Filters may also be used to control algae in water. Both pressure and gravity filters may reduce algae with the help of pretreatment.

SUMMARY

Coagulation is a process whereby finely divided particles of turbidity and color, capable of remaining in suspension indefinitely, are combined by chemical means into masses sufficiently large to effect rapid settling. (Formation of masses of gelatinous precipitates in water by adding alum or other suitable chemicals for clarifying water.) Coagulation is essential for filtration in order to remove the fine particles of turbidity.

Some of the coagulants are: aluminum sulfate, filter alum, ammonium alum, sodium aluminate, ferric sulfate, chlorinated copperas, ferric chloride, and ferrous sulfate.

The jar tests are performed to indicate the approximate dosages and optimum pH values. The final adjustments are made in the full-sized equipment.

Optimum pH - is the pH at which best floc formation occurs; usually the floc forms and settles fastest at this point.

Sedimentation is a process of removing suspended solids from water by gravity or settling.

Clarification is a process used to make or cause a liquid to become pure and clear.

Hard water is objectionable because it deposits scale in pipes and boilers, leaves stains on glassware and kitchen utensils, and requires excessive amounts of soap to form lather. Hardness is caused by calcium and magnesium compounds in solution in the water. Iron and aluminum compounds also produce hardness but usually in such small quantities that they are not generally associated with hardness. Water with over 200 ppm of these compounds is classed as "very hard" while water with 15 ppm is termed "very soft."

In the lime soda process, softening is accomplished by changing these compounds from a soluble form to an insoluble form and removing them through sedimentation and filtration. Both carbonate and noncarbonate hardness can be removed in this manner. Some supplementary softening procedures that may have special application include the excess lime treatment, split treatment, excess lime and recarbonation, and the addition of aluminum compounds.

To the water and waste processing specialist, "scale" is a substance which results from using hard water for industrial purposes. There are several kinds of scale; however, the most common is a white, crusty deposit of $CaCO_3$. Scale deposits are very objectionable because they reduce safety factors, stop up pipes, reduce rate of heat transfer and increase amount of required maintenance. The best way to prevent scale is to remove the hardness from the water before it is used in any kind of industrial equipment. For some purposes, stabilization of the hardness compounds by the addition of polyphosphates or CO_2 will work satisfactorily.

Corrosion is the deterioration of metal due to an unfavorable environment. The most practical corrosion prevention measures for the inside surfaces of equipment through which water circulates consist of pH control (keep the pH of the water above 7) and the addition of surface active, water soluble, corrosion inhibiting chemicals. The chemicals most frequently added to prevent corrosion are sodium hydroxide and polyphosphates.

QUESTIONS

1. What is meant by clarification?

2. What happens during sedimentation?

3. How can floating sediment be removed from raw water?

4. What is "floc"?

5. What are the two primary groups of coagulants?

6. How does hard water affect the making of a soap lather?

7. How would water containing 75 ppm of hardness be rated?

8. Name two compounds that cause permanent hardness.

9. What type feeder is used to feed chemicals when the water flow is variable?

10. What troubles develop when water contains over 0.3 ppm of iron?

11. Name one method of removing dissolved iron.

12. Name three advantages of the sludge-blanket type of softener.

13. What chemicals does the clarifier use in softening water?

14. What type of softening may be used in treatment plants not designed for softening?

15. Why does softened water also need stabilization?

16. What is water scale formed of in a pipeline?

17. Name the four bad effects of scale.

18. How can scaling be stopped or reduced?

19. What effect does pH of water have on pipeline corrosion?

20. Name two chemicals used to control algae.

REFERENCES

1. Betz Handbook in Industrial Water Conditioning

2. AFM 85-13, Maintenance and Operation of Water Plants and Systems

3. Water Treatment for Industrial and Other Uses (Nordell)

4. Water Conditioning for Industry - Powell

5. TM5 - 295 - Military Water Supply

6. AFM 85-12, Operation and Maintenance of Central Heating Plants and Distribution Systems

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WATER SYSTEM FILTERS

OBJECTIVE

The purpose of this study guide is to aid you in learning about water system filters and their relation to the water supply and distribution systems.

INTRODUCTION

A working knowledge of water system filters is necessary in your job as a water and waste processing specialist. In the water purification process, water from the sedimentation basins is brought to the water filters. This water contains very fine and suspended matter such as minute particles of clay, mud, and floc that have not formed together. It will also contain bacteria and microscopic organisms that have not been removed by sedimentation; therefore, the purpose of the filter is to remove suspended matter and give the water a clear and sparkling appearance.

Water system filters will be discussed under the following main topics:

- TYPES OF FILTERS
- FILTER MEDIA
- DESIGN FEATURES
- OPERATION OF FILTERS
- DIATOMACEOUS EARTH FILTERS
- RADIOLOGICAL CONTAMINATION
- OPERATIONAL PROBLEMS AND CORRECTIONS
- WASHING PROCEDURES

TYPES OF FILTERS

Water filters are classified into two types; slow sand and rapid sand filters. Both filters can be used in Air Force installations; however, the rapid sand filters are the most commonly used.

Slow Sand Filters

Slow sand filters contain fine-grain sand and have low filtration rates. These are normally used when coagulation is not included in the treatment process; however, use of slow sand filters by the Air Force has been practically discontinued because of their initial high cost, the high cost of labor required to clean them, and the large surface area of land required.

Rapid Sand Filters

Rapid sand filters are normally used by the Air Force in modern water treatment plants. The two types of rapid sand filters discussed are gravity and pressure.

GRAVITY FILTERS. See figure 1. Granity filters are usually open-top rectangular concrete boxes about ten feet deep. An underdrain system at the bottom of the gravity type filter is covered by about 12 inches of gravel which in turn supports a 24 to 30 inch layer of fine filter sand or other filtering agent (see figure 2).

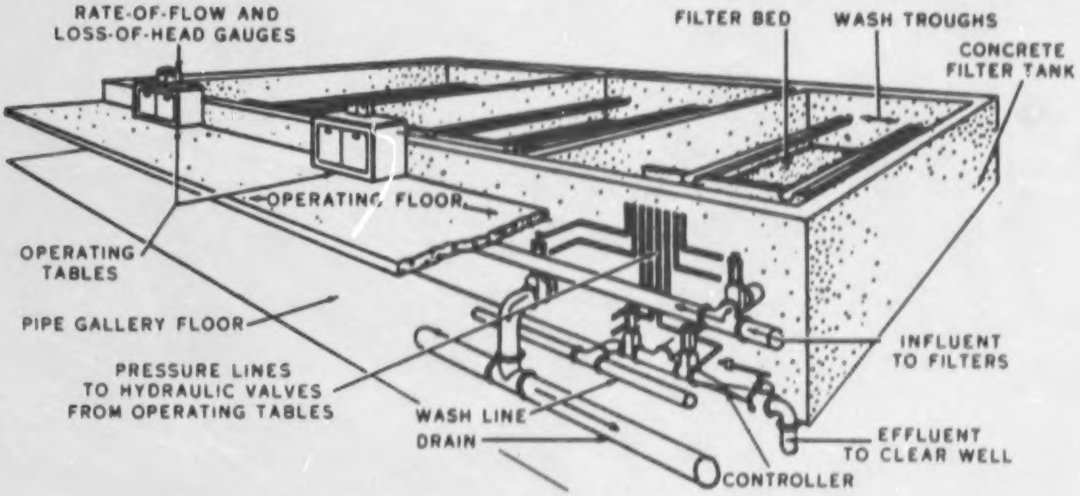

RATE-OF-FLOW AND LOSS-OF-HEAD GAUGES
FILTER BED
WASH TROUGHS
CONCRETE FILTER TANK
OPERATING FLOOR
OPERATING TABLES
PIPE GALLERY FLOOR
PRESSURE LINES TO HYDRAULIC VALVES FROM OPERATING TABLES
INFLUENT TO FILTERS
WASH LINE
DRAIN
EFFLUENT TO CLEAR WELL
CONTROLLER

Figure 1. Gravity Type Rapid Sand Filter

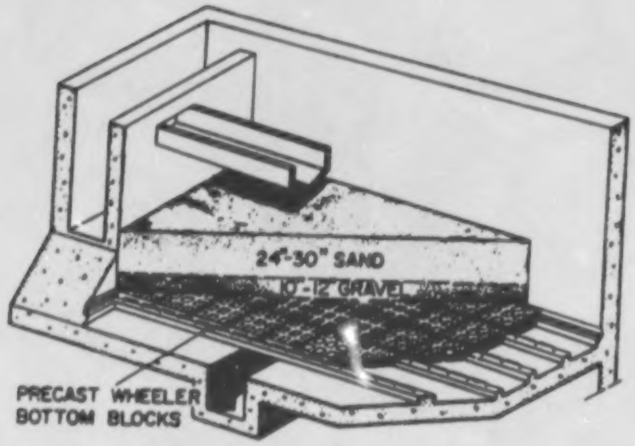
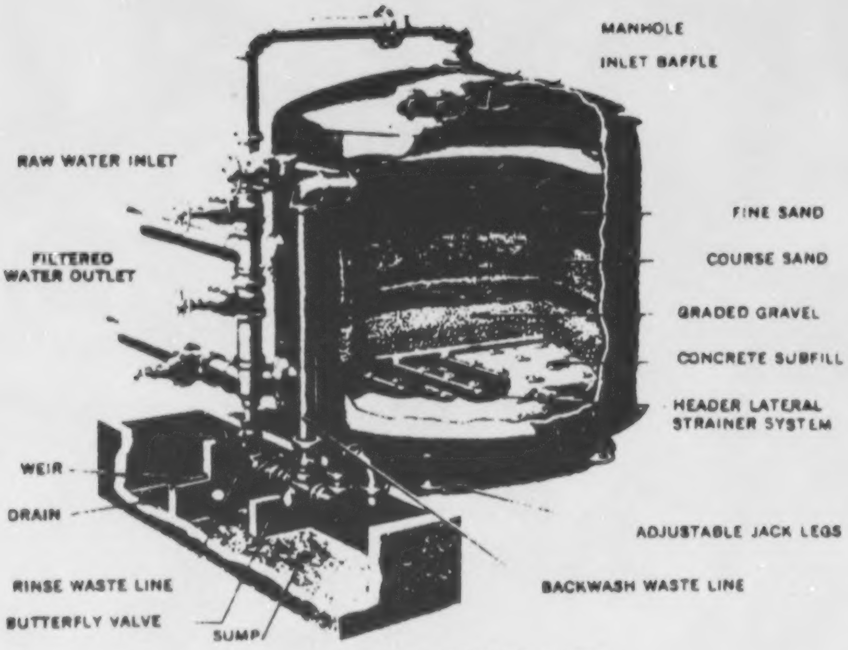


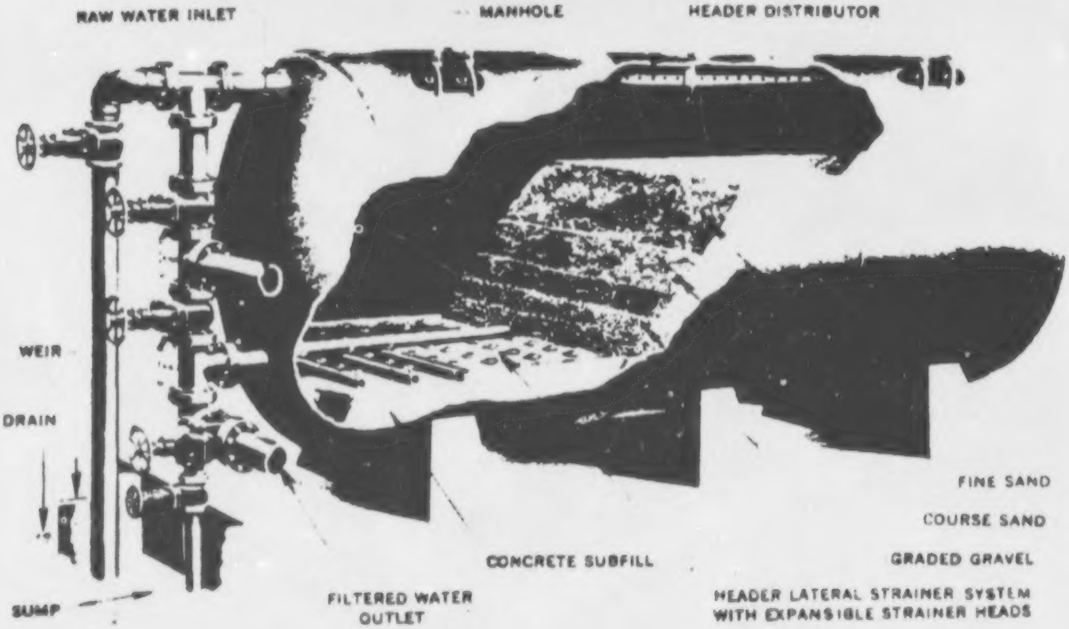
Figure 2. Cutaway of Gravity Type Filter

Gravity filters are normally designed to filter about two gallons per minute per square foot of filter-bed area; however, as much as four gallons per minute per square foot can be filtered during an emergency if prior treatment by flocculation and sedimentation produces very low turbidity, and if prechlorination and postchlorination are disinfecting the water efficiently. Approval must be obtained from the major command to operate filters at rates in excess of 2 gpm per square foot.

PRESSURE FILTERS. See figure 3. Pressure filters have the filter bed enclosed in a pressure vessel. Water is either pumped into the vessel and forced through the filter or is drawn through the filter by a suction pump. Pressure filter tanks can be installed either vertically or horizontally (see figure 3). This type of filter will operate on the same principle and at the same flow rate as gravity filters.


MANHOLE
INLET BAFFLE
RAW WATER INLET
FINE SAND
FILTERED WATER OUTLET
COURSE SAND
GRADED GRAVEL
CONCRETE SUBFILL
HEADER LATERAL STRAINER SYSTEM
WEIR
DRAIN
ADJUSTABLE JACK LEGS
RINSE WASTE LINE
BACKWASH WASTE LINE
BUTTERFLY VALVE
SUMP

VERTICAL PRESSURE FILTER


RAW WATER INLET
MANHOLE
HEADER DISTRIBUTOR
WEIR
DRAIN
FINE SAND
COURSE SAND
CONCRETE SUBFILL
GRADED GRAVEL
SUMP
FILTERED WATER OUTLET
HEADER LATERAL STRAINER SYSTEM WITH EXPANSIBLE STRAINER HEADS

HORIZONTAL PRESSURE FILTER

Figure 3. Pressure Filters

FILTER MEDIA

The filter media most commonly used by the Air Force water systems are (1) sand, (2) anthrafilt, and (3) filter gravel. Each filter agent must meet rigid specifications.

Filter Sands

Filter sand is made up of sharp or rounded durable grains of clean quartz or quartzite material. The quartz will be between 0.35 and 0.70 millimeters. Of course, the size of the sand grain will be used as an index to determine the filtration rate.

Anthrafilt

Anthrafilt is a filtering medium obtained from freshly mined anthracite coal. Some of the specifications of anthrafilt are (1) it must be free of dirt and other foreign material; (2) the anthrafilt grains will be 0.65 to 0.75 mm in diameter; (3) ash content is less than eleven percent; and (4) it will weigh about 53 pounds per cubic foot.

Filter Gravel

Filter gravel has three primary purposes: (1) it supports the sand; (2) it permits water to flow freely to the underdrain; and (3) it aids in distributing wash water to all parts of the sand in a uniform manner. Specifications that must be met are: (1) it must consist of hard, rounded, and durable pebbles; (2) it must weight100 pounds per cubic foot; and (3) it must be washed and be free of loam, sand, clay, dirt, shells, and other foreign matter.

DESIGN FEATURES

The purpose of underdrains is to provide an outlet for the water after it has passed through the filtering agents. Design of the underdrain system is controlled mainly by the wash water requirements. This is so because the rate of application of wash water is greater than the rate of filtering.

A pipe-type underdrain system consists of a cast-iron manifold or header with laterals usually on six inch centers. The laterals are closed at the other ends, but have calibrated holes drilled in the upper and lower sides. Total area of all the orifices is about one-third of the filter surface area (see figure 4).

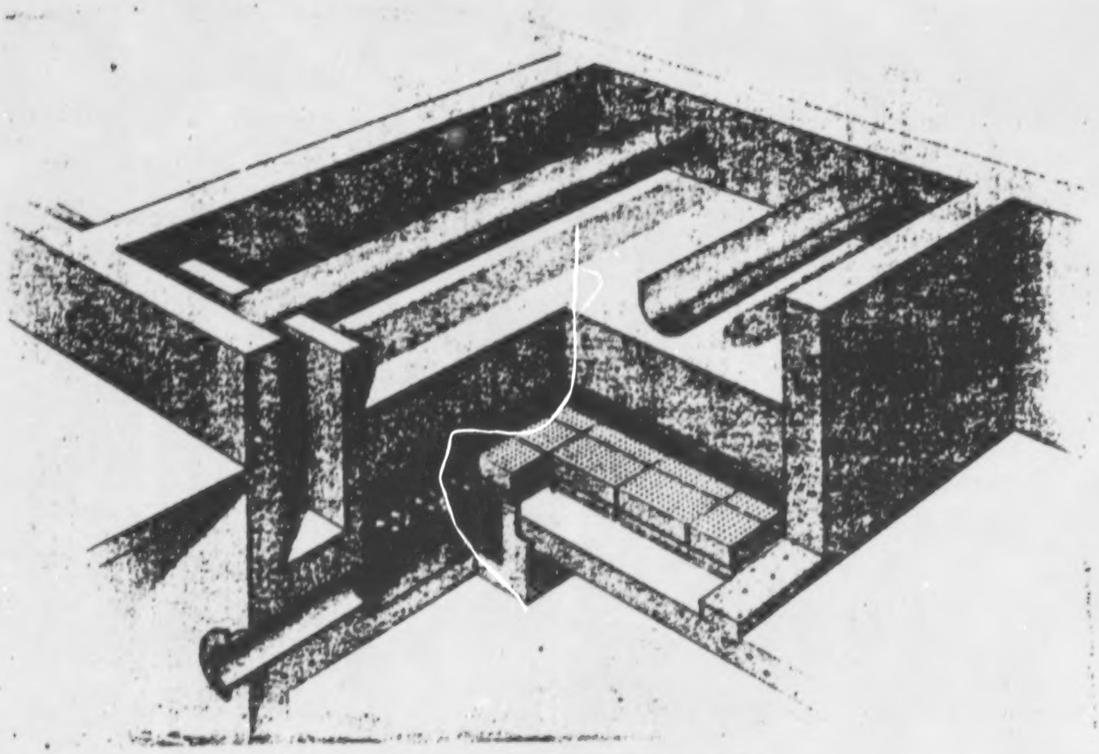


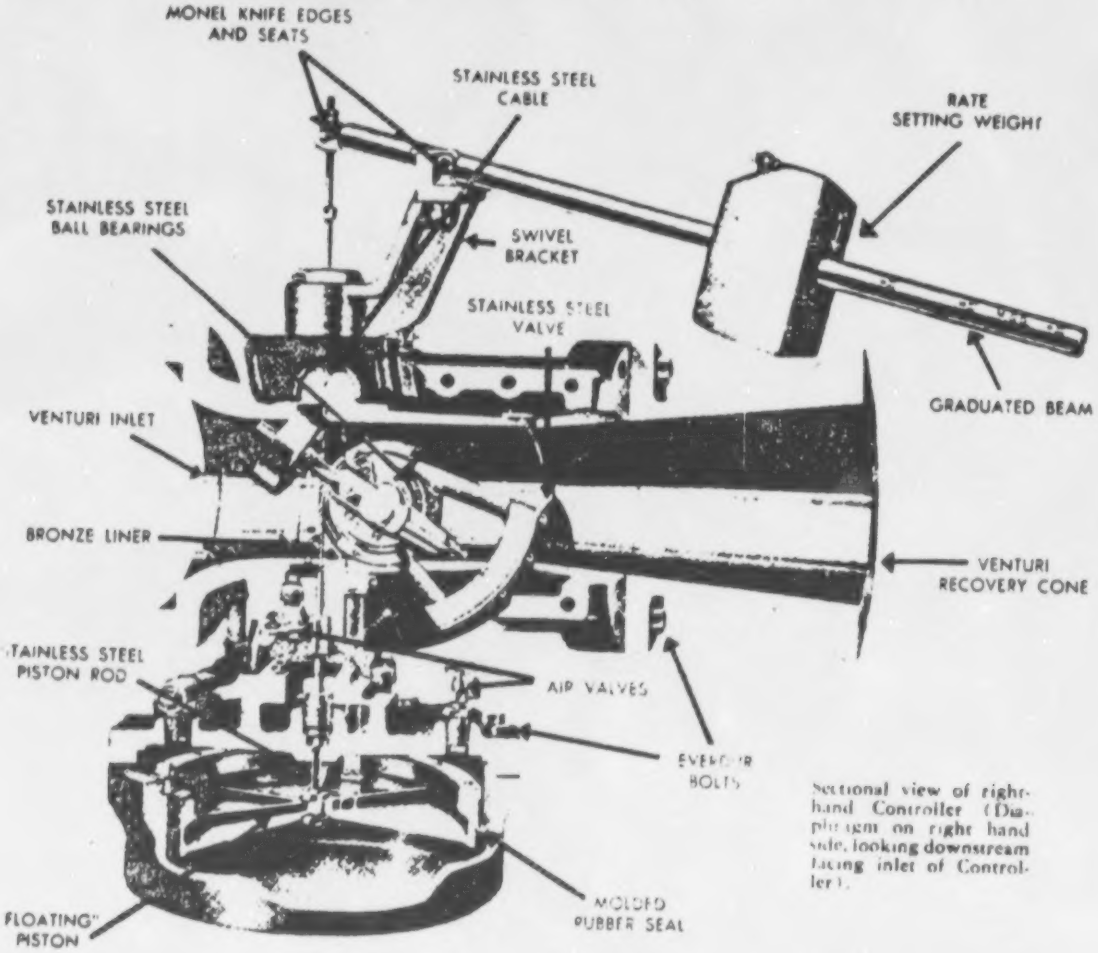
Figure 4. Underdrain System

OPERATION OF FILTERS

In order to be able to understand the operation of filters, you must have a working knowledge of the filtering equipment, such as, the rate-of-flow controller, loss-of-head gage, wash-water controller, and rate-of-flow indicator. Each one of these components will be described and then integrated in an explanation of filter operation.

Rate-Of-Flow Controller

The purpose of the rate-of-flow controller (see figure 5) is to regulate the flow of water through a filter bed. When a filter bed is first put into operation or if it has been washed recently, the water will flow through it too rapidly for effective filtration. As a result, the filter outlet line must be restricted to reduce the flow of the water. As the filter bed becomes clogged with foreign matter, the filtration flow rate decreases. The restriction will then be reduced in order to maintain a stable filtration rate. A pressure operated automatic mechanism known as a rate-of-flow controller will accomplish the steady flow rate through the filter. The rate-of-flow controller is usually installed in the water filter outlet line. Its operation is controlled by filtered water flowing through a venturi tube. Pressure differentials will be produced by the venturi tube and will actuate a balanced valve. The balanced valve in turn will affect the flow rate by partially opening or closing the flow valve.


MONEL KNIFE EDGES AND SEATS
STAINLESS STEEL CABLE
RATE SETTING WEIGHT
STAINLESS STEEL BALL BEARINGS
SWIVEL BRACKET
STAINLESS STEEL VALVE
GRADUATED BEAM
VENTURI INLET
BRONZE LINER
VENTURI RECOVERY CONE
STAINLESS STEEL PISTON ROD
AIR VALVES
EVERDUR BOLTS
"FLOATING" PISTON
MOLDED RUBBER SEAL

Sectional view of right-hand Controller (Diaphragm on right hand side, looking downstream facing inlet of Controller).

Figure 5. Rate-of-Flow Controller

Rate-Of-Flow Indicator

The flow rate of the water out of the filter is measured by the rate-of-flow indicator. It will usually consist of a venturi meter which is located in the filter outlet line. The indicating instrument itself will be installed on the operating floor where it can be observed by the operator.

In some equipment it will be included with the loss-of-head gage or the rate-of-flow controller. This gage must be observed frequently since a constant and controlled rate of filtration is necessary. Changes in the filtering rate may cause breaks in the filter bed which would allow portions of the water to pass through the filter without being filtered.

Loss-Of-Head Gage

As the water passes through the filter, foreign matter is deposited in the filter. This foreign matter produces a greater resistance to the flow of the water through the filter bed and underdrain; consequently, there is a loss in head pressure between the inlet and outlet of the filter. This loss of head pressure is measured by the loss-of-head gage (see figure 6). This gage is operated by two floats, one at the surface of the

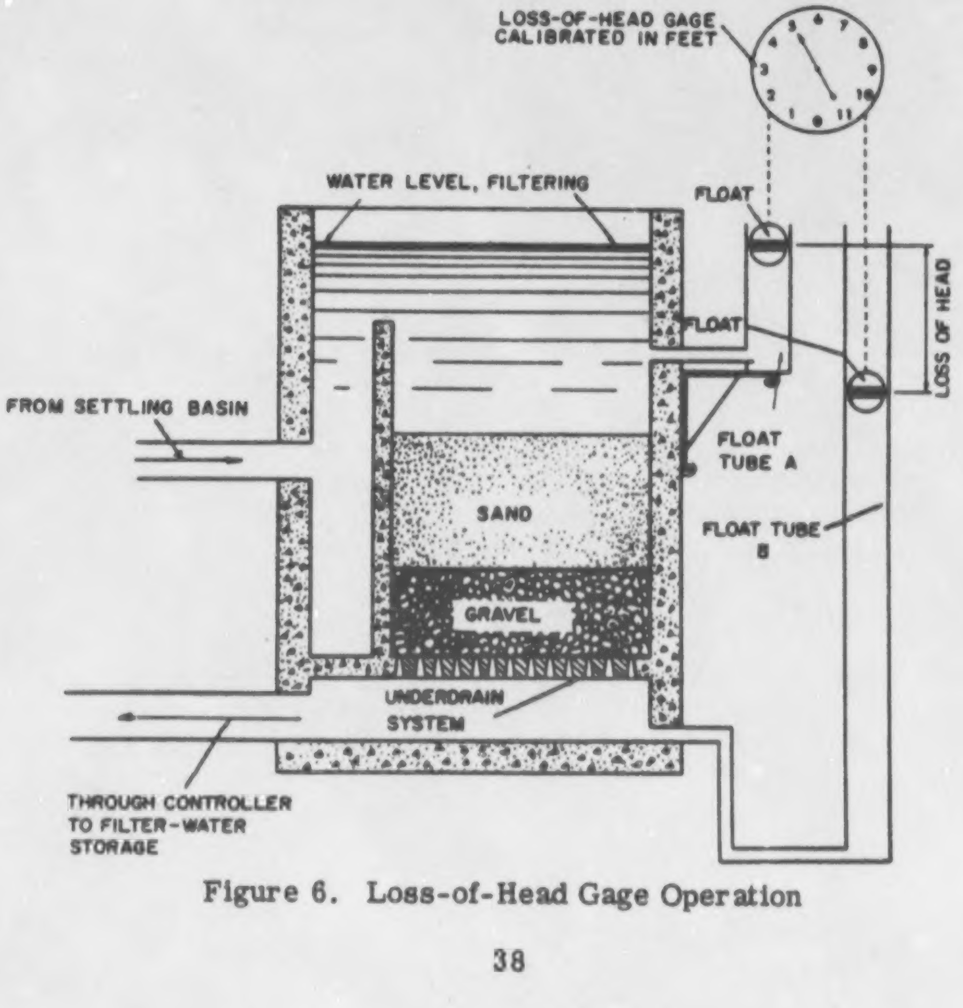

LOSS-OF-HEAD GAGE CALIBRATED IN FEET
WATER LEVEL, FILTERING
FLOAT
FLOAT
LOSS OF HEAD
FROM SETTLING BASIN
FLOAT TUBE A
SAND
FLOAT TUBE B
GRAVEL
UNDERDRAIN SYSTEM
THROUGH CONTROLLER TO FILTER-WATER STORAGE

Figure 6. Loss-of-Head Gage Operation

water in the filter and the other at the static operating level of water in the underdrain. These two levels or pressures will be reflected by the calibrated face of the loss-of-head gage and portrays a very accurate guide for efficient filter operation. This gage should be checked periodically for operation and accuracy. Loss-of-head gage erratic readings can identify such problems as (1) cracks in the filter bed surface, (2) improper operation of the rate-of-flow controller, (3) malfunctioning automatic outlet valves, and (4) the need for washing of the filter.

Wash-Water Controller

When the filter has become clogged and must be washed, a wash-water controller is used to control the flow rate of the water from the wash-water tank through the filter. This valve or controller must not be opened too quickly as it may cause air, which has accumulated in the bottom of the filter, to compress. This air pressure can be released only through the filter bed which will violently disturb the arrangement of the sand and gravel. The valve control mechanism will be located on the operating floor.

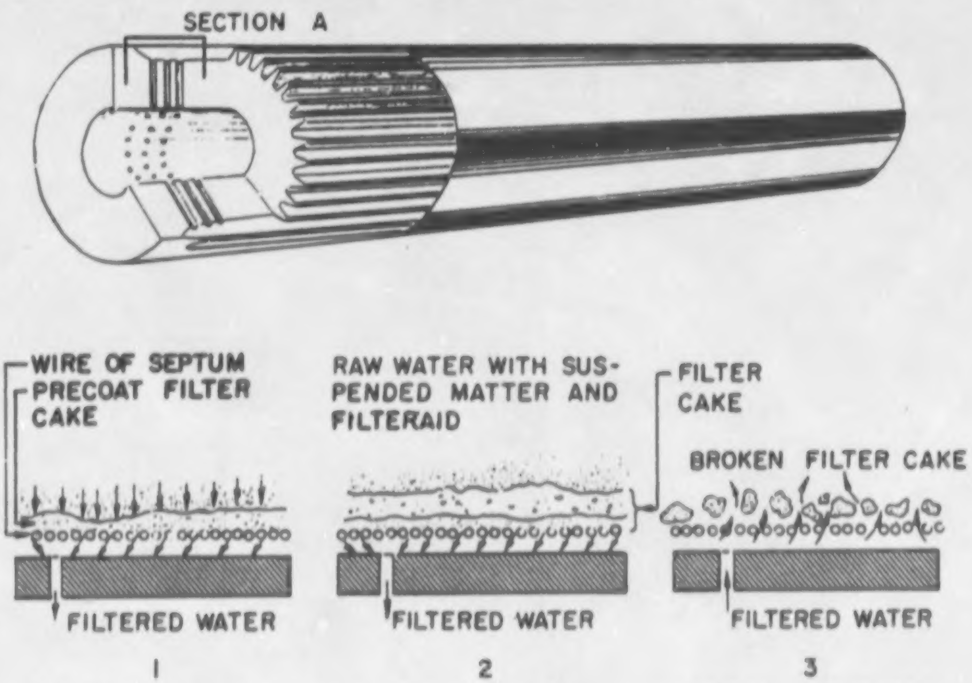
Filter Operation

In reference to the operation of filters refer to figure 6. An inlet pipe transports water from the sedimentation basin to the filter. The water will be discharged against the filter baffle. This prevents the water current from disturbing the filter bed. The incoming water flows up and over the filter. The water filters downward through the sand and gravel into the underdrain system. The outlet flow of the water from the filter is regulated by the rate-of-flow controller. The filtered water is collected at this point in the process in a filtered-water reservior called a clearwell. The main operating difficulties in water filters are: (1) mud or mud ball accumulation, (2) sand incrustation, (3) air binding, (4) sand clogging, (5) formation of micro-organisms and (6) ice formation.

Pressure Filters

Pressure filters are generally composed of two types of filtering agents: sand and diatomaceous earth. Pressure filters (figure 3) will be used in filtering the main water supply as well as for swimming pools. The diatomaceous earth pressure filter (figure 7) will be used primarily because it will require less space than sand filters and it will produce sparkling clear water. Diatomaceous earth is composed of skeletons of countless tiny one-celled animals called diatoms which, when specially prepared, looks like powdered chalk. The diatomaceous earth will build up on the filtering element and form a cake deposit. This causes a formation of fine pores between the particles, and filters the water as it passes through the cake deposit.

The filtering elements, (figure 7), of the pressure filter in the center of the tank are cylindrical and perforated. A single depth of fine wire is wound around the cylinder. This fine wire element is close enough to prevent the diatomaceous earth from passing through the filter. The diatomaceous earth deposits evenly to form a thin coating, called the pre-coat, over the filter element.


SECTION A
WIRE OF SEPTUM
PRECOAT FILTER CAKE
RAW WATER WITH SUSPENDED MATTER AND FILTERAID
FILTER CAKE
BROKEN FILTER CAKE
FILTERED WATER
FILTERED WATER
FILTERED WATER
1
2
3

SECTION A DURING PRECOATING
Flow of filteraid in suspension is greatest through thinnest portion of filter cake, building up that portion and resulting in uniform coating of filteraid over entire element.

SECTION A DURING FILTERING
Porosity of the filter cake is maintained under pressure by rigid particles of filteraid mixing with compressible particles of suspended matter in raw water.

SECTION A DURING BACKWASHING
In backwashing, filtered water drawn through septum dislodges and breaks filter cake; then discharges it from bottom of filter tank.

Figure 7. Pressure Filter Element

Pressure filters are much more widely used than gravity filters. They are usually built to withstand a pressure of 50 to 65 pounds per square inch. Vertical filters range in size from 1 to 10 feet in diameter. Horizontal filters are usually about 10 feet in diameter and about 25 feet in length. The operation of these filters is basically the same as gravity filters except that water is forced through the filter bed under pressure.

The flow rate through a pressure filter is about 3 gpm per square foot of filter area. When the head loss reaches 5 pounds per square inch, the filter area. When the head loss reaches 5 pounds per square inch, the filter should be backwashed. The backwash rate is about 12 to 15 gallons per minute per square foot.

The main advantages of pressure filters over the gravity type are (1) they are less costly to install; (2) they are free from air binding; and (3) they eliminate double pumping. The biggest disadvantage is that the efficiency of operation of the filter cannot be directly observed. A typical vertical steel shell pressure filter in shown in figure 8.

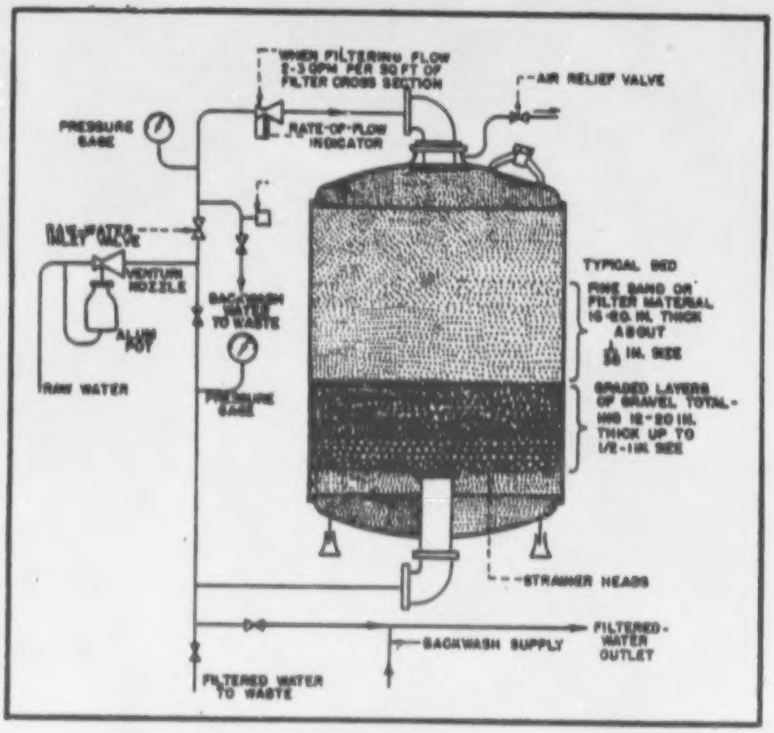
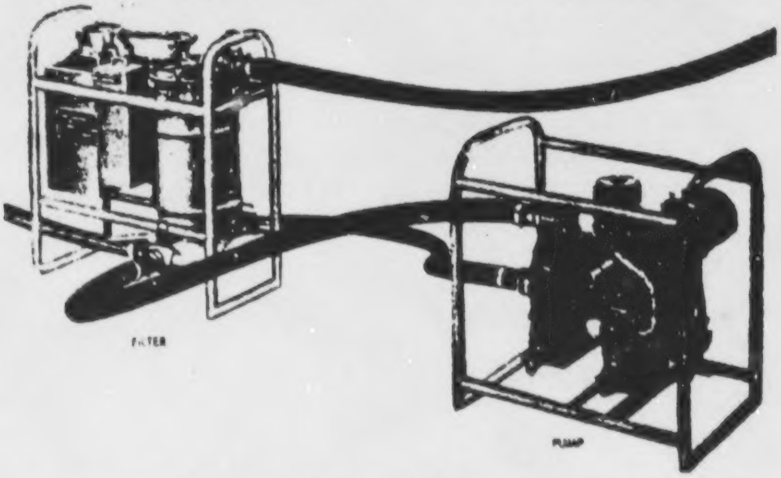

WHEN FILTERING FLOW 2-3 GPM PER SQ FT OF FILTER CROSS SECTION
AIR RELIEF VALVE
PRESSURE GAGE
RATE-OF-FLOW INDICATOR
RAW WATER INLET VALVE
VENTURI NOZZLE
ALUM POT
BACKWASH WATER TO WASTE
RAW WATER
PRESSURE GAGE
TYPICAL BED
FINE SAND OR FILTER MATERIAL 16-20 IN. THICK ABOUT 1/32 IN. SIZE
GRADED LAYERS OF GRAVEL TOTALING 12-20 IN. THICK UP TO 1/2-1 IN. SIZE
STRAINER HEADS
FILTERED-WATER OUTLET
BACKWASH SUPPLY
FILTERED WATER TO WASTE

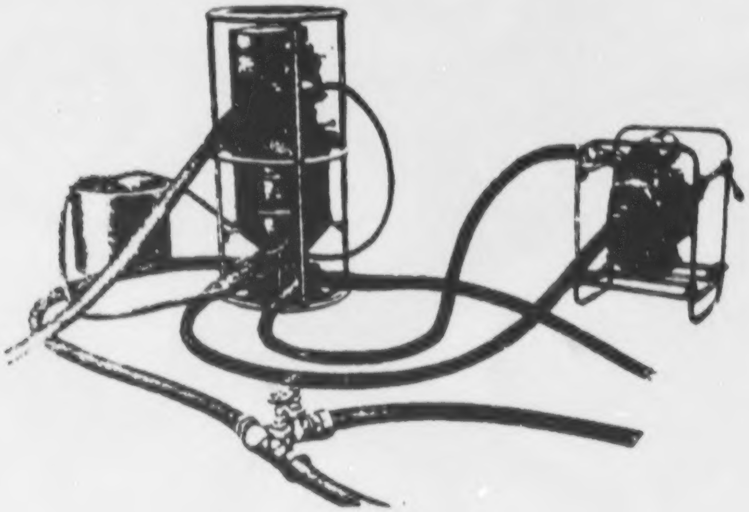
Figure 8. Vertical Steel Shell Pressure Filter

DIATOMACEOUS EARTH FILTERS

Diatomite purification equipment is available in 15, 35, and 50 gpm portable sets (see figure 9). This equipment and auxiliary supplies consist of a pressure filter unit, a diatomite feeding apparatus, pre-coat tank, fabric tanks, gasoline-driven pumping sets, suction hose,



Diatomite water purification set No. 2, 15 gpm



Diatomite water purification set No. 3, 35 gpm

Figure 9

coagulating chemicals, two chemical feet baskets, a measuring container, and a chest containing discharge hose, fittings, residual chlorine, and pH testing equipment. The variances in the 15, 35, 50 gpm diatomite purification equipment or sets is as follows:

	Set No. 2	Set No. 3	Set No. 4
Average Output	15 gpm	35 gpm	50 gpm
Pumping Sets	4 each	4 each	5 each
Fabric Tanks	4 each-500 gal.	3 each-3,000 gal.	4 each-3,000 gal.
Suction Hoses	1 inch	1-1/2 inch	2 inch

The purpose of the diatomite equipment is to provide potable and safe water for Air Force personnel in the field. All the purification sets mentioned above were specifically designed to remove all amoebic cysts and the cercariae of schistosome. Pre-treatment is necessary for efficient operation of a diatomite filter. The complete layout for all purification sets is similar, as represented in figure 10, and includes the process of coagulation, sedimentation, disinfection, and filtration to produce water of the highest quality regardless of the turbidity of the source.

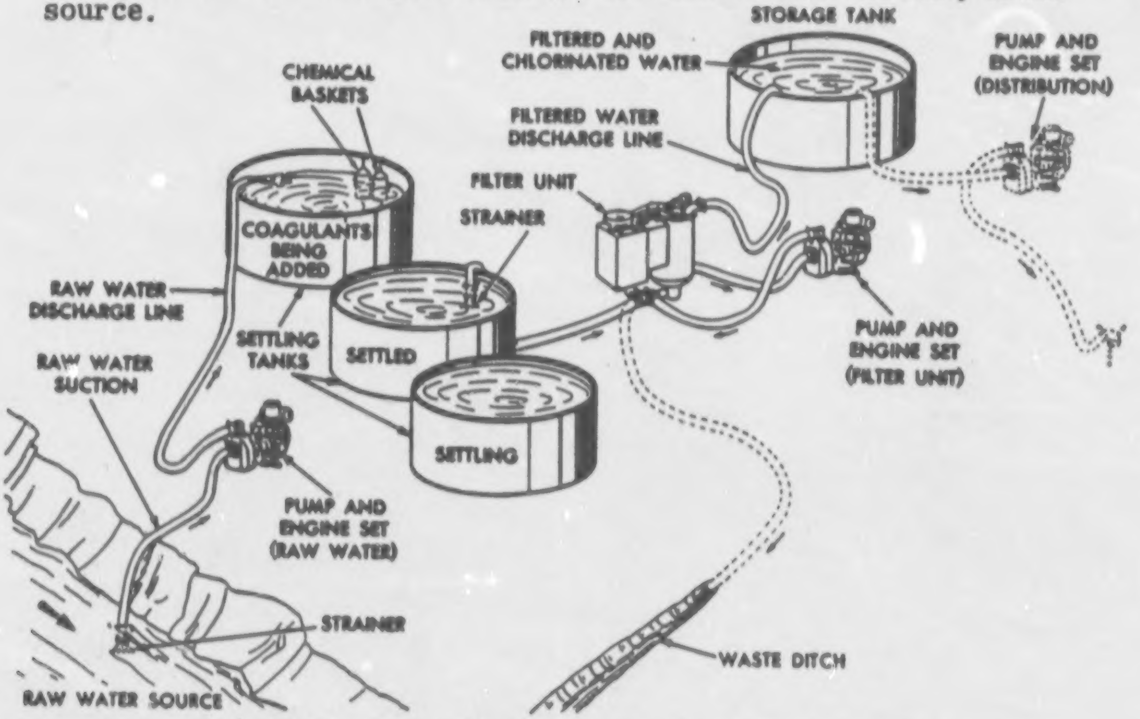

STORAGE TANK
FILTERED AND CHLORINATED WATER
PUMP AND ENGINE SET (DISTRIBUTION)
CHEMICAL BASKETS
FILTERED WATER DISCHARGE LINE
FILTER UNIT
STRAINER
COAGULANTS BEING ADDED
RAW WATER DISCHARGE LINE
RAW WATER SUCTION
SETTLING TANKS
SETTLED
SETTLING
PUMP AND ENGINE SET (FILTER UNIT)
PUMP AND ENGINE SET (RAW WATER)
STRAINER
WASTE DITCH
RAW WATER SOURCE

Figure 10. Portable Water Purification Equipment

The maximum production of the purification sets is as follows:

Rated Capacity or Filter	Maximum Output Per 20-Hour Day
15 gpm	15,000 to 18,000 gallons
35 gpm	40,000 to 45,000 gallons
50 gpm	50,000 to 60,000 gallons

The equipment just described is referred to as batch type equipment. The batch type equipment will be eventually replaced by the continuous flow type of purification equipment (see figure 11). The continuous flow type will allow purification of water under all climatic conditions. Detailed instructions on operation and layout are found in TM 5-4610-202-10, TM 5-4610-203-10, and TM 5-4610-204-10 which corresponds to the federal stock number.

Figure 11. Van Type Water Purification Unit

The knapsack pack water purification unit consists of a small hand operated diaphragm pump, paper filter pads, canvas carrying case, sterilizing tablets (halazone), and accessories. This unit was designed to provide individual Air Force personnel with equipment by which they could produce potable and safe water. It will filter water of high clarity from turbid raw water at 1/4 gpm. Amoebic cysts and cercariae of the schistosome will be removed from water and it will reduce bacteria concentration (see figure 12)

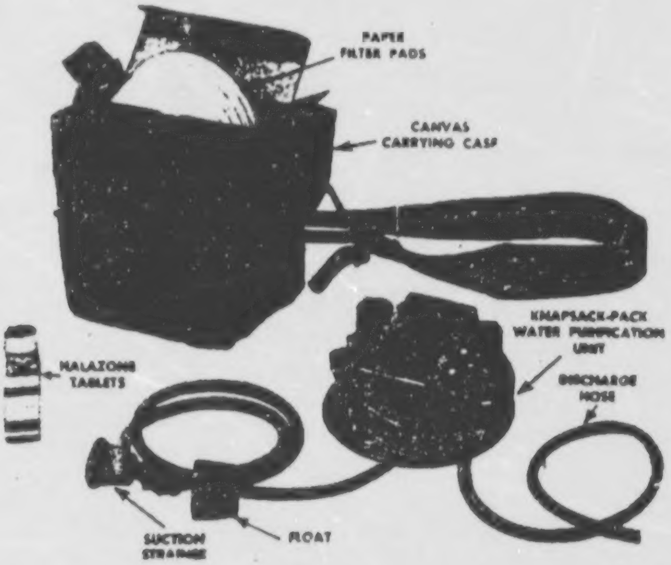


Figure 12. Knapsack Pack Water Purification Unit

Raw water is drawn by the diaphragm pump through the suction strainer and discharged in receiving chambers above and below the filter disk. The water is filtered and discharged. This pump is self-priming and will deliver one quart per minute when hand pumped at 70 to 80 strokes per minute. When the pump lever is pushed down, the pump diaphragm discharges water from the pump. When spring action brings the lever back up, water is drawn into the pump. When the pump lever is depressed, the outlet poppet valve opens to allow discharge of the water. When the pump lever returns to the normal up position, the inlet poppet valve opens allowing raw water to be drawn into the pump. Thus, the inlet and outlet valves will operate in opposite positions (see figure 13).

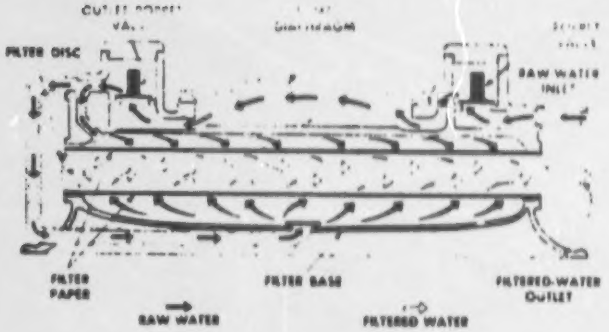


Figure 13. Flow Diagram of Water Through Knapsack-Pack Unit

RADIOLOGICAL CONTAMINATION

This can be removed by most any filter with; pretreatment, coagulation, and filtration. It can also be removed by the ion-exchange methods. Removal of suspended radioactive materials by this method is very high. Removal of dissolved radioactivity depends primarily upon the nature of the radioisotopes. The use of pretreatment and coagulation will remove approximately 0 to 90 percent. The ionic methods remove 90 to 100 percent of all isotopes. The pre-treatment methods use clay high in aluminum silicate, superchlorination, and acidification.

OPERATIONAL PROBLEMS AND CORRECTIONS

Clogging of Filters

Normally, filters become clogged only at the surface, and can be restored readily by use of washing methods stated later in this study guide. Sometimes the entire sand bed becomes clogged or caked which destroys the filtering capability. If this is the case, it can be restored only by removing the sand and gravel from the filter and thoroughly washing it in special solutions or replacing with new sand or gravel. The filter may become completely clogged if: (1) the backwashing procedure is incomplete; (2) the rate of flow of the water is too slow; (3) the water being filtered is extremely turbid; and (4) alum is allowed to leave the sedimentation tank and reach the filter bed.

Clogged filters can be determined by sweeping a rake through the sand bed while it is being backwashed, or by probing down to the gravel bed during the backwashing procedure.

Air Binding of Filters

Air binding occurs when pockets of air accumulate in the sand. It interferes with proper filtration, as indicated by high loss of head. Air binding can be caused by (1) insufficient water above the sand during normal filtering operation, (2) rapid fluctuations in water head, (3) filling filter too rapidly after washing, and (4) allowing water level to drop below the surface of the sand during operation.

Air binding can be corrected by first filling the filter bed slowly from the wash water tank. This must be done carefully to prevent violent agitation of the sand bed. Second, the depth of the water in the top of the filter must be greater than total loss of head through the filter. This will prevent formation of air pockets. Usually, the water depth above the sand is about 5 feet. This will allow a loss of head of 7 to 9 feet before the filter begins to form air pockets. Third, wide fluctuations in head during operation may cause air pockets to form and explode the sand.

WASHING PROCEDURES

After a filter has been in service for some time, foreign material will have collected to the extent that the loss of head has become excessive. It is then necessary that the filter be washed or "back-washed" to clean the sand bed. This is usually accomplished when the loss of head has reached a point of 7 to 9 feet or after 50 hours of service. The filter bed is washed by reversing the flow of filtered water through the gravel and sand. This loosens the sand bed and washes the foreign matter from the grain surfaces. The wash water rises into the wash troughs and carries the foreign matter into the water plant sewer.

Methods of Washing

Although there are some differences in the construction of filters, the basic operation and washing are the same. The main differences are in operating controls, instruments, and gages. In small plants having manual operation, it is necessary to operate each valve and controller by hand. Usually in manual operation, the loss-of-head gage is the only gage that will be used in filtering operation. In more elaborate plants the valves will be operated remotely by push-button control. The method or procedure for washing a filter (see figure 14) is as follows:

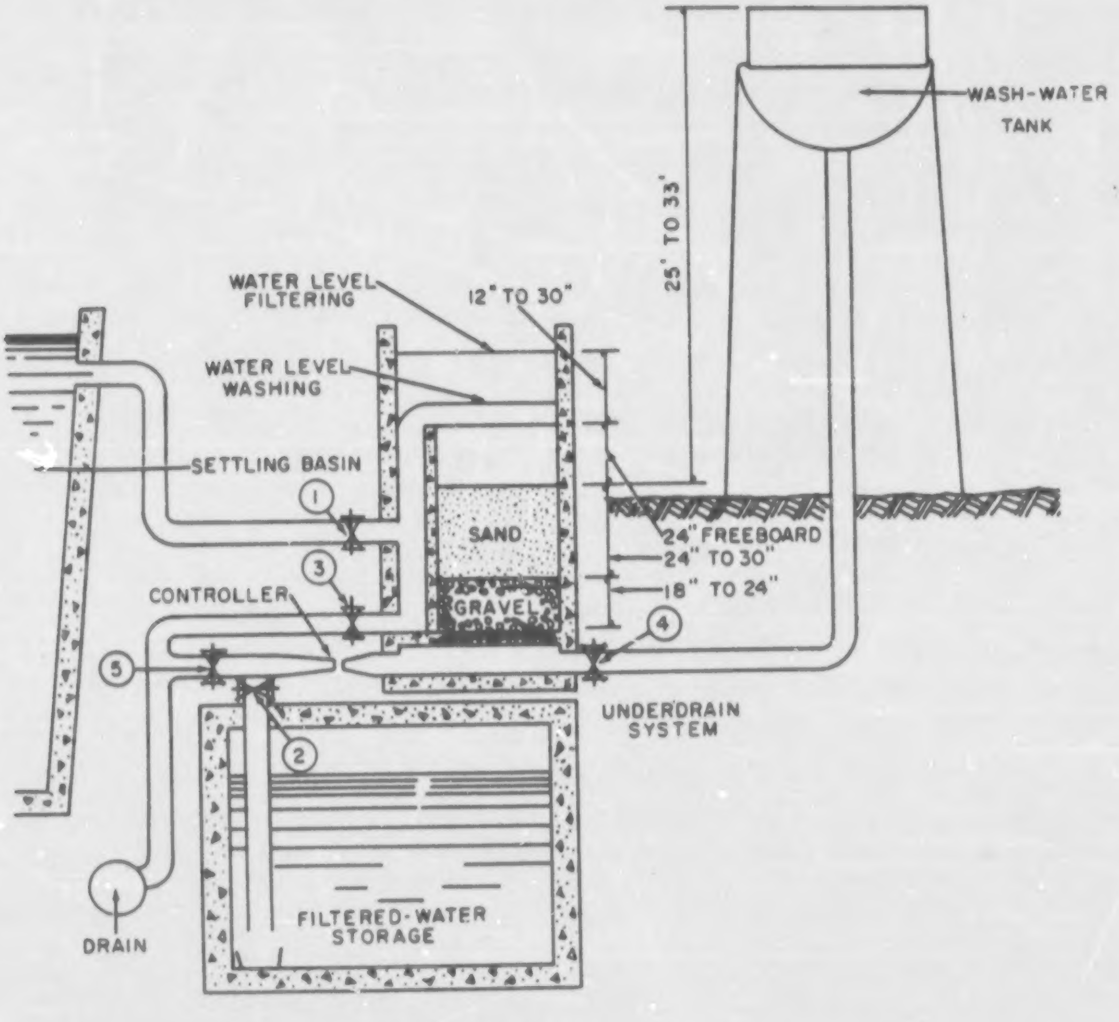

WASH-WATER TANK
25' TO 33'
WATER LEVEL FILTERING
12" TO 30"
WATER LEVEL WASHING
SETTLING BASIN
①
SAND
③
CONTROLLER
GRAVEL
④
⑤
②
24" FREEBOARD
24" TO 30"
18" TO 24"
UNDERDRAIN SYSTEM
DRAIN
FILTERED-WATER STORAGE

Figure 14. Filter Washing Procedure

1. Close filter influent valve "A" and allow the water to continue to filter until the water level is about 6 inches above the surface of the sand.

2. Close the clearwell influent valve "B" which will discontinue operation of the filter.

3. Open filter gullet effluent valve "C" which will allow inlet water to drain.

4. Open wash-water control valve "D" slowly which will bring in the water from the wash-water tank.

5. Allow the wash-water to flow upward through the sand bed for 3 to 10 minutes until the water has cleared.

6. Close wash-water control valve "D" which isolates wash-water source.

7. Close filter gullet effluent valve "C" which will isolate the filter from the drain.

8. Open filter influent valve "A" and drain isolation valve "E" for about two minutes to allow wash-water to drain out of filter.

9. Close drain isolation valve "E" to open clearwater influent valve "B" which places the filter back into normal operation.

10. During normal filtering operation, valves "A" and "B" are open, and valves "C", "D", and "E" are closed.

AIR WASH. Air wash, or agitation with air, is used at some water plants to supplement water washing. It is more efficient in cleaning the filter element than the water wash. Water in the filter will be drained to a low level. Air of 3 to 5 p.s.i. is directed to the lower side of the gravel bed. The air is applied prior to normal backwash. Use of air wash may reduce the quantity of wash water by as much as fifty percent.

SURFACE WASH. Surface washing is a method of filter cleansing which is supplementary to the conventional reverse flow or back-washing. The washing equipment will consist primarily of a rotary distributor with horizontal arms and spray nozzles located above the filter-bed surface (see figure 16). The nozzles point downward at an angle of 45 degrees to the sand surface. Agitation by high water pressure from water jets scrubs the sand grains of foreign matter. The jets also furnish the force required to rotate the pipe arms. The filter will be surface washed for about one minute. Normal filter washing will then be accomplished.

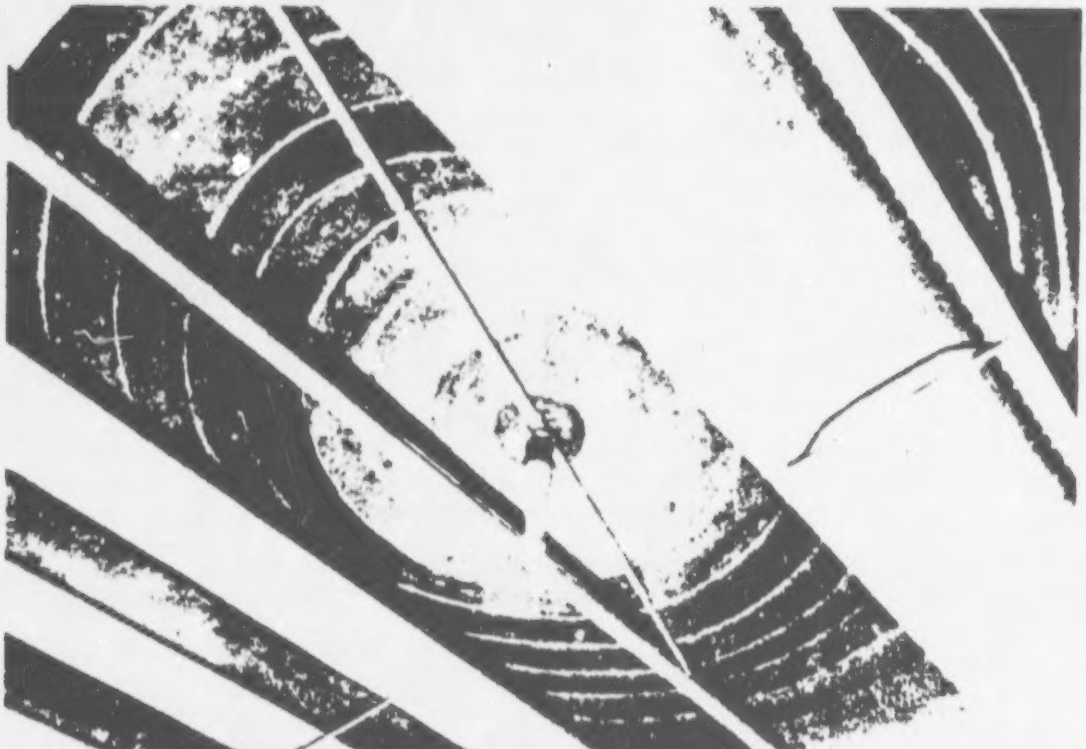

SAND OR ANTHRAFILT
SECTION THROUGH FILTER

Figure 16. Surface Wash

SUMMARY

The purpose of filtration is to remove suspended solids by passing water through a porous medium. This is performed by: (1) flocculation, (2) sedimentation, and (3) straining.

Water filters are classified as slow sand and rapid sand. The most commonly used filter is the rapid sand filter which is built in two forms; gravity and pressure.

The main filtering agents used by the Air Force are sand, anthrafilt, and filter gravel. Each filtering agent must meet rigid specifications.

The primary filtering equipment is the rate-of-flow controller, loss-of-head gage, and wash-water controller. A thorough understanding of these units will give insight into the operation of filters.

Pressure filters will have filtering agents of sand and diatomaceous earth. Advantages of pressure filters are: (1) cheaper to install, (2) free from air binding and (3) the elimination of double pumping.

In order to maintain efficiency in operation of filters, it is necessary to back-wash the filters. Back-washing can be accomplished either manually or automatically. Air wash and surface wash can be used to supplement the water washing of the filters.

Diatomaceous earth portable filters used in the field have capacities of 15, 35, and 50 gpm. These are used to provide potable and safe water for Air Force personnel in the field. In order to have small individual supplies of water, the knapsack pack will be used.

QUESTIONS

1. Why is it necessary for the water and waste processing specialist to understand water system filters?
2. Name three methods by which suspended matter can be removed from water.
3. Explain the flocculation process.
4. List two types of water filters.

5. Why are rapid sand filters used primarily by the Air Force?
6. Identify two types of rapid sand filters.
7. Describe the construction of gravity type filters.
8. List three kinds of filter media.
9. What is the purpose of the rate-of-flow controller?
10. List four problems that can cause an erratic loss-of-head gage reading.
11. Describe the operation of a gravity flow filter.
12. List two types of pressure filters.
13. What are the advantages of diatomaceious earth filters over sand filters?
14. Explain the operation of diatomaceous earth filters.
15. Why is it necessary to wash filters periodically?
16. Name two filter washing methods that are supplementary to backwashing with water.
17. List four factors that will cause water filters to clog.
18. What is air binding within a filter?
19. What is the purpose of portable diatomite earth filters?
20. What impurities can the knapsack pack water purification unit remove from raw water?

REFERENCES

1. AFM 85-13, Maintenance and Operation of Water Plants and Systems
2. TM 5-700 Field Water Supply

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METHODS OF DISINFECTION AND PURIFICATION

OBJECTIVE

The purpose of this Study Guide is to aid you in learning why there is a need for disinfecting water supply systems, the disinfectants used, methods and equipment used in treatment, its operation and safety precautions to be observed.

INTRODUCTION

Disinfection is a necessary step in the insuring of a safe water supply. It is almost impossible to secure a natural water supply free of bacteria and impurities. Therefore, man must treat and disinfect his water supply before he can drink it without risk. The most commonly used disinfectant is chlorine. It is the disinfectant normally specified for Air Force use. Disinfection is the process of destroying disease producing organisms. There is also the possibility of water becoming recontaminated from handling before consumption. Therefore, a slight chlorine residual is provided for after purification to combat secondary contamination.

This information will be discussed under the following main topics:

- NEED FOR DISINFECTION
- CHEMICALS USED
- METHODS OF CHLORINATION
- CHLORINATION EQUIPMENT
- CHLORINATION CONTROLS
- CHLORINATION OPERATION AND SAFETY PRECAUTIONS

This study guide will not contain all the information you will need to know; therefore, the study of additional material is recommended and listed at the end of this study guide.

NEED FOR DISINFECTION

People with the problem of supplying satisfactory water to a single family or to a city must meet the rigid specifications placed upon this service by the consumer. These specifications require the water to be safe, free from tastes and odors, clean, cheap, and in abundant supply.

The clear, cool spring water of past years which was pure and uncontaminated represents the water supply that must be duplicated today to meet the needs of the consumer. Unfortunately, nature does not provide pure water supplies sufficient for all needs. It is necessary, therefore, to make the supplies we have meet our requirements. Contaminated water must be made free of disease bearing organisms. Hard water must be made soft. Cloudy water must be made clear. Tastes and odors must be removed. All of these things must be done inexpensively so that all may have the finished product in abundance. Man is fortunate in having various means of purifying water supplies, the main one being chlorination.

The beneficial effects of chlorination upon the general health of our nation is almost unbelievable. Water-borne disease including typhoid fever was very common before chlorination but is rarely encountered today. Whether applied as hypochlorite or chlorine, the chlorination of water is the most important treatment used to make raw water potable.

In this day, when man's interests carry him both far and near, no water supply may be considered entirely safe without chlorination. The most remote reservoir may be contaminated overnight by a careless camper. Shallow wells may easily be contaminated by polluted surface water. Deep wells may be contaminated at any time by polluted water through a break in the casing or the opening of a lead to a polluted stream previously not connected. All raw water, from the clearest and purest to the most turbid, should be chlorinated before being used for human consumption.

CHEMICALS USED

Chlorine is the disinfectant normally specified for Air Force use. It is presently the only widely accepted agent that destroys organisms in water and leaves an easily detectable residual that serves as a tracer element. Its sudden disappearance may signal contamination in the system. Under ordinary temperatures and pressures, chlorine is a greenish yellow gas that is 2.5 times heavier than air. Its activity as a disinfectant depends on the temperature and pH of the water to which it is added. Disinfecting action is faster at higher temperatures, but is retarded by high pH. If the pH is above 8.4, the rate of disinfection decreases sharply. Chlorine may also be used to control tastes and odors, nuisance bacteria, remove iron, and assist in coagulation.

Chlorine disinfectants are available in a number of different forms. For procurement see AFM 67-1.

Liquid Chlorine

Liquid chlorine is a liquefied gas under pressure and is shipped in seamless steel cylinders under Interstate Commerce Commission regulations. The gas has a strong, pungent odor. The liquid is a clear amber color. In a moisture free state, it is relatively noncorrosive. In the presence of moisture, it is highly corrosive, and is an irritant to the respiratory system and the skin. The standard sizes of shipping containers are the 150-pound cylinder and the one ton container. Each pound of liquid chlorine produces about five cubic feet of chlorine gas at atmospheric pressure and a temperature of 68°F. A standard chlorine institute valve and a protective valve hood are screwed into the neck of each cylinder. The valve has a safety plug containing fusible metal that softens between 157° and 162°F., protecting the cylinder from bursting in case of fire. All cylinders must be factory tested every five years; 150-pound cylinders are tested at 500 pounds pressure, one-ton containers at 800 pounds pressure.

Calcium Hypochlorite

Calcium hypochlorite, $Ca(OCl)_2$ is a relatively stable, dry, granule or powder in which the chlorine is readily soluble, and is prepared under a number of trade names including HTH, Perchloron, and Hoodchlor. It is furnished in three to 100-pound containers and has 65 to 70 percent of available chlorine by weight. Because of its concentrated form and ease of handling, calcium hypochlorite is preferred over other hypochlorites.

Sodium Hypochlorite

Sodium Hypochlorite, NaOCl, is generally furnished as a solution that is highly alkaline and, therefore, reasonable stable. Federal specifications l for solutions having five and ten percent available chlorine by weight. pping costs limit its use to areas where it is available locally. It is o furnished as powder under various names such as Lobax and HTH-15. e powder generally consists of calcium hypochlorite and soda ash, which ct in water to form sodium hypochlorite.

lcium Hypochloride

Calcium Hypochloride, also known as chloride of lime and bleaching vder, is a low-grade calcium hypochlorite testing about 35 percent ilable chlorine when fresh. However, it deteriorates rapidly in hot ist atmosphere and should, therefore, be purchased in small packages t can be kept effectively sealed. Calcium hypochloride contains an ex- ss of insoluble lime, hence, solutions should be prepared in a separate tainer, the lime permitted to settle, and the liquid decanted into a sep- te tank for use.

lorine Dioxide

Chlorine dioxide, ClO_2, is produced by adding sodium chlorite solu- n at the discharge end of a gas chlorinator and running the mixture through mall contact chamber before introducing it into the water. It has 2.5 es the oxidizing power of chlorine and is effective in taste and odor trol. Experiments indicate that it may be a better bactericide than orine in nonpolluted waters where it is not used up in oxidation before bactericidal action can take place.

SCELLANEOUS. Miscellaneous purification methods and agents are as lows:

- Water may be disinfected by boiling vigorously for two or three minutes.
- Ozone released in water from atmospheric oxygen will act as disinfectant. The ozone is produced from dry air by an electric discharge. It is only slightly soluble in water and requires a thorough mixing to be effective.
- Ultraviolet ray may be utilized as a disinfectant. In this method, the water flows in a thin stream past or around special lamps which give off ultraviolet rays. The rays are ineffective in colored or turbid waters.

- Halazone or iodine tablets may be used for emergency or field disinfection of water in small quantities. These tablets are used one or two to a canteen of water.

- Lime is used quite extensively in water softening plants and it will also disinfect the water. Its use has been restricted to commercial plants because of the skilled operation required to give satisfactory results.

- Potassium permanganate and silver may also be used as disinfectants.

REACTIONS. When chlorine is introduced into pure water, it reacts to form hypochlorous acid, HOCL, and hydrochloric acid, HCL.

Chlorine disinfectants are available in a number of different forms. For procurement see AFM 67-1.

$$Cl_2 \text{ and } H_2O \longrightarrow HOCL \text{ and } HCL$$

The chlorine ion of the hydrochloric acid does not contribute to purification reactions. It is the hypochlorous acid which actually kills microbial organisms present in water. Some may remain in molecular solution as Cl_2. These forms of chlorine are termed free available chlorine, since their oxidizing and disinfecting ability are fully available. However, most natural waters contain small amounts of ammonia and nitrogenous organic substances. Free available chlorine reacts with these to form chloramines, such as NH_2Cl, and other complex chlorine-nitrogen compounds. These forms are termed combined chlorine, since part of the oxidizing and disinfecting ability of the chlorine is lost. Both free available and combined chlorine further react with substances in the water until their oxidizing and disinfecting ability is depleted. The amount of chlorine required to react with these substances in a given time, usually ten minutes, is called the chlorine demand. Chlorine remaining in excess of the chlorine demand is the total chlorine residual, or residual chlorine. This is composed of both free available and combined chlorine, as determined by the orthotolidine test; the two forms are differentiated by the orthotolidine-arsenite or OTA test. The time elapsing between the introduction of chlorine and the use of the water is termed the contact period.

Definitions

(1) Residual chlorine is the term which is applied to the available chlorine which remains after the chlorine demand (amount of chlorine required to destroy bacteria and organic matter) has been satisfied. Presence of residual chlorine in a water supply is insurance against noncontamination. At fixed installations, a chlorine residual content of 0.4 ppm is required at all times.

(2) Free available chlorine. Refers to the chlorine present in solution as hypochlorous acid and hypochlorite ion present in the water. These are the most effective disinfecting forms of chlorine. The relative amount of each present in the water is dependent upon the pH value of the water. It is important to remember that when the pH is raised, the quantity of free available chlorine required to kill the same number of micro-organisms increases. With a decrease in temperature an increase of dosage is required to maintain the same number of micro-organisms killed.

(3) Combined available chlorine. The chlorine present in water which reacts with ammonia or nitrogen to form chloramines.

(4) Total available residual chlorine is the sum of free available chlorine and the combined available chlorine.

(5) Chlorine dosage. Dosage is the amount of chlorine added to water to satisfy the chlorine demand as well as to provide a residual after a specified time. The dosage is usually stated in terms of parts per million (PPM).

(6) Chlorine demand. Demand is the amount of chlorine which reacts with chlorine-consuming agents in a specific amount of time. Chlorine demand varies with the nature and quantity of chlorine-consuming agents, the pH value and the temperature of the water, and the contact period.

(7) Disinfecting time. Chlorine demand in most water is virtually satisfied ten minutes after chlorine is added. When one PPM chlorine residual remains after the ten-minute period, satisfactory disinfecting action usually results after an additional 20 minutes of contact.

Effectiveness

(1) Chlorine residual. Effectiveness increases rapidly with increase in residual. However, free available chlorine is much more effective than combined chlorine, so that the relative amount of each in the total residual is important.

(2) Contact period. The required contact period is inversely proportional to residual, within normal limits. Thus, if the residual is halved, the required contact period is doubled.

(3) Temperature. Effectiveness at 35° to 40°F. is half of that at 70° to 75°F.

(4) pH. Effectiveness is highest at pH below 7.0. At pH 8.0, it is half and at pH 9.0, it is one-fourth to one-sixth as effective as at pH 7.0.

(5) Points of application. Plain or simple chlorination is the single application of chlorine to unfiltered supplies before discharge into the distribution system, as for example, the chlorination of ground water supplies and previously unchlorinated purchased supplies. Prechlorination is the application of chlorine to raw water before coagulation, sedimentation, and filtration. Postchlorination is the application after filtration but before the water leaves the treatment plant. Rechlorination is the application at points in the distribution system or to a previously chlorinated purchased supply to maintain the chlorine residual. The above applications are normally continuous. Very heavy chlorination for a limited period is applied at specific points of the distribution system to destroy localized contamination.

(6) Chlorination policy. For policy on chlorine residuals and contact periods to be maintained at Air Force installations, see AFM 160-4.

Areas Requiring Special Treatment

Amoebic cysts are best removed by diatomite filtration preceded by adequate coagulation and settling. When this is not possible, water suspected of containing cysts, if moderately clear with pH of 7 or less, can be disinfected by adding enough chlorine to produce a residual slightly greater than 2 PPM after a 30-minute contact period.

When schistosomiasis is a problem and diatromite filters are not available, reasonable protection can be obtained by adding enough chlorine to produce a residual of one PPM after 30 minutes contact.

Maintaining a safe chlorine residual in swimming pool water is even more important than maintaining it in drinking water. This is because drinking water is protected, while swimming pool water is constantly contaminated by the bathers. Water spit out by one bather may quickly be swallowed by another. The length of time the chlorine has to act may be very short. Hence, chlorine residuals must be kept very high. At all Air Force swimming pools, the free available chlorine residual shall be maintained between 0.4 and 0.6 PPM. In addition to killing bacteria rapidly, this level of chlorine residual will prevent the growth of algae.

Water mains, wells, filters, storage tanks, and other units of a water supply system become contaminated during construction and repair. Flushing the system to remove dirt, waste, and surface water which is introduced is the first step, but is not a sufficient safeguard. To insure a safe water supply, each unit of the system must be thoroughly disinfected before it is placed in operation.

The chemicals used in disinfecting a water system are the same as those used in disinfecting the water. Hypochlorite solution or chlorine gas are most commonly used.

Chlorine dosage required to disinfect any unit thoroughly depends on contact time, and amount of jute, untarred hemp and organic chlorine consuming material present. Under average conditions the following minimum dosages are recommended.

Unit	Dosage (PPM)
Pipe	50
Storage Tank	50
Filter	100
Well	150

The volume of water in the unit to be disinfected must be computed before chlorine dosage can be estimated.

METHODS OF CHLORINATION

Marginal chlorination

Marginal chlorination is the application of chlorine to produce the desired total chlorine residual without reference to the relative amounts of free available and combined chlorine present. It is so termed because the initial chlorine demanded has been satisfied, but some oxidizable substances remain; it is the usual type of chlorination. Its bactericidal effectiveness is not predictable within close limits.

Chlorine-ammonia treatment.

Chlorine-ammonia treatment consists of adding both ammonia and chlorine to form chloramines. This compound provides a persistent chlorine residual and reduces any unpleasant chlorine taste. Chloramine reacts so slowly that a very long contact period is needed for complete destruction of microorganisms. To reduce this, chlorine may be applied first, and after the shorter contact period necessary for the bacterial kill, the ammonia is introduced. With proper chlorine-ammonia dosages the chloramine residual is usually two to four times greater than those normally carried in marginal chlorination.

Break-point chlorination.

Break-point chlorination is the application of chlorine to produce a residual of free available chlorine, with no combined chlorine present. As chlorine is added, the total residual increases gradually after the initial demand of the water has been satisfied. At some residual concentration, depending on the nature of the water treated, free available chlorine reacts with any remaining oxidizable substances, including combined chlorine, and the residual drops sharply. When all combined chlorine has been oxidized by reaction with free available chlorine, the residual, now consisting only of free available chlorine rises again and continues to increase in direct proportion to increased dosage. The point at which the residual again begins to increase is the break point. Advantages of break point chlorination are high bactericidal efficiency, long lasting residuals, and low taste and odor characteristics. The application of break point chlorination procedure before instead of after filtration has been found to be desirable.

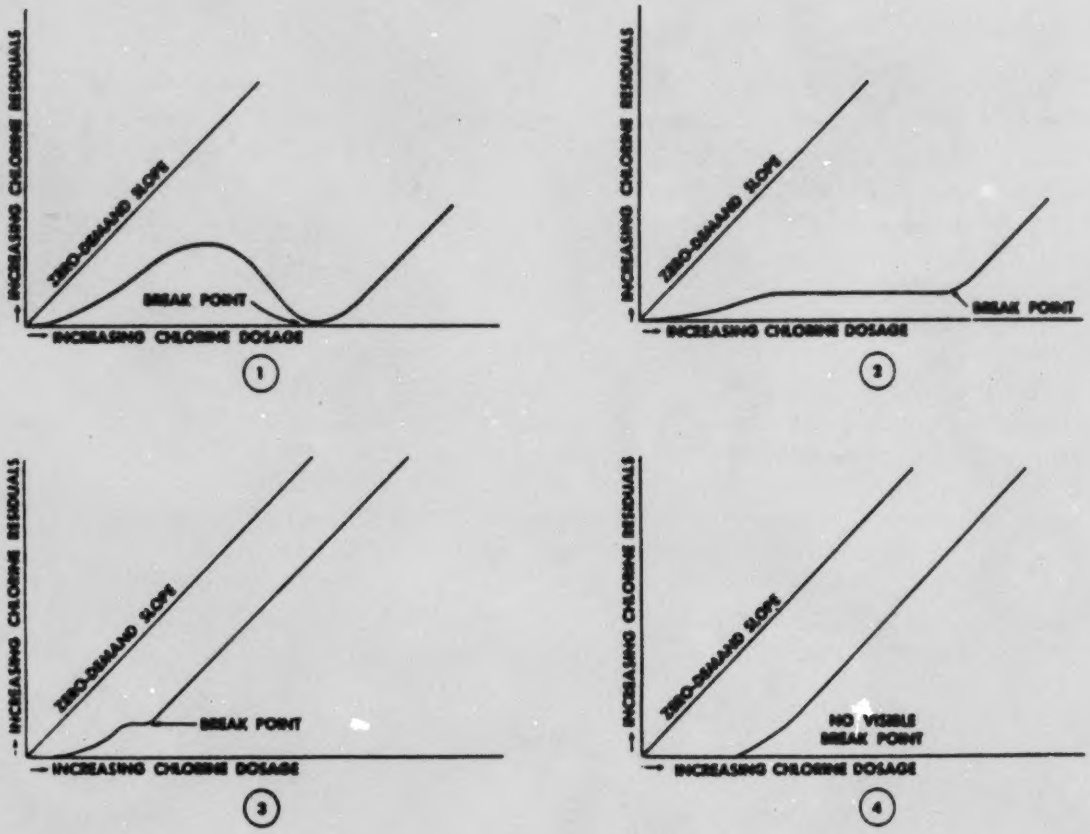

Figure 1. Break-Point Chlorination Curves

Superchlorination

Superchlorination is the application of more chlorine than needed for the chlorine residual essential to marginal chlorination; this is done to control tastes and odors. This method is particularly valuable in surface waters with variable ammonia and organic content. The surplus chlorine is later removed by aeration or by a dechlorinating agent such as sulphur dioxide or activated carbon. Sulphur dioxide reacts with chlorine to form acids which are neutralized by the natural alkalinity of the water. It is fed by equipment similar to that used for chlorine feeding. Activated carbon absorbs excess chlorine and is removed by settling or filtration; aeration removes excess chlorine by dissipation to the atmosphere.

CHLORINATION EQUIPMENT

Chlorination equipment to feed chlorine gas or hypochlorite solution is of three general types, depending on methods of control. In the manually controlled type, equipment must be started and stopped manually, and rate of feed must be manually adjusted to rate of water flow. In the semiautomatic type, equipment starts and stops automatically as water flow starts and stops, but must be manually adjusted to rate of water flow. This type is normally used with a water pump having fairly uniform delivery. In the fully automatic type, rate of feed is automatically adjusted to rate of flow of water being treated. The differential pressure of a metering device is used to accomplish this. In all types, the ratio of feed to water treated, or dosage, is set by manual adjustment. Chlorinators may also be classified generally as direct feed and solution feed. Direct-feed machines are designed to operate without a pressure water supply, feeding the chlorine gas directly to the flow to be treated. Solution-feed machines dissolve the gas in a minor flow of water and inject the resultant solution into the flow to be treated. They require a pressure water supply for operation. Chlorinators are also classified by the type of diaphragm used in controlling the chlorine feed. There are two types, the water diaphragm and the mechanical diaphragm. The water diaphragm machine is always vacuum type, solution feed machine and has the advantages of a friction free, puncture-proof water diaphragm. The mechanical diaphragm machine may be either direct or solution-feed vacuum type only.

Direct Feed Chlorinators

Direct feed chlorinators are used chiefly as emergency equipment and on small installations where it is not possible to obtain a water supply suitable for operating a solution feed machine. They cannot be used where the pressure of the water being treated is more than 20 p.s.i. and are limited in the types of semiautomatic or automatic controls which may be used. Due to chlorine being under pressure as a gas at all times, direct feed machines are highly susceptible to leakage of the gas to the atmosphere with resultant corrosive action on adjacent equipment and structures.

Solution Feed Chlorinators

Solution feed chlorinators introduce chlorine gas into the water supply by means of a chlorine solution usually formed by drawing chlorine gas into the jet stream of water at the low pressure point of an injector mechanism of the chlorinator. Two general types are used in the water works, the bubbling or pulsating reduced pressure type and the vacuum type. Because they keep the chlorine under a partial vacuum, they cause fewer chlorine leaks than pressure gas chlorinators and direct diffusers.

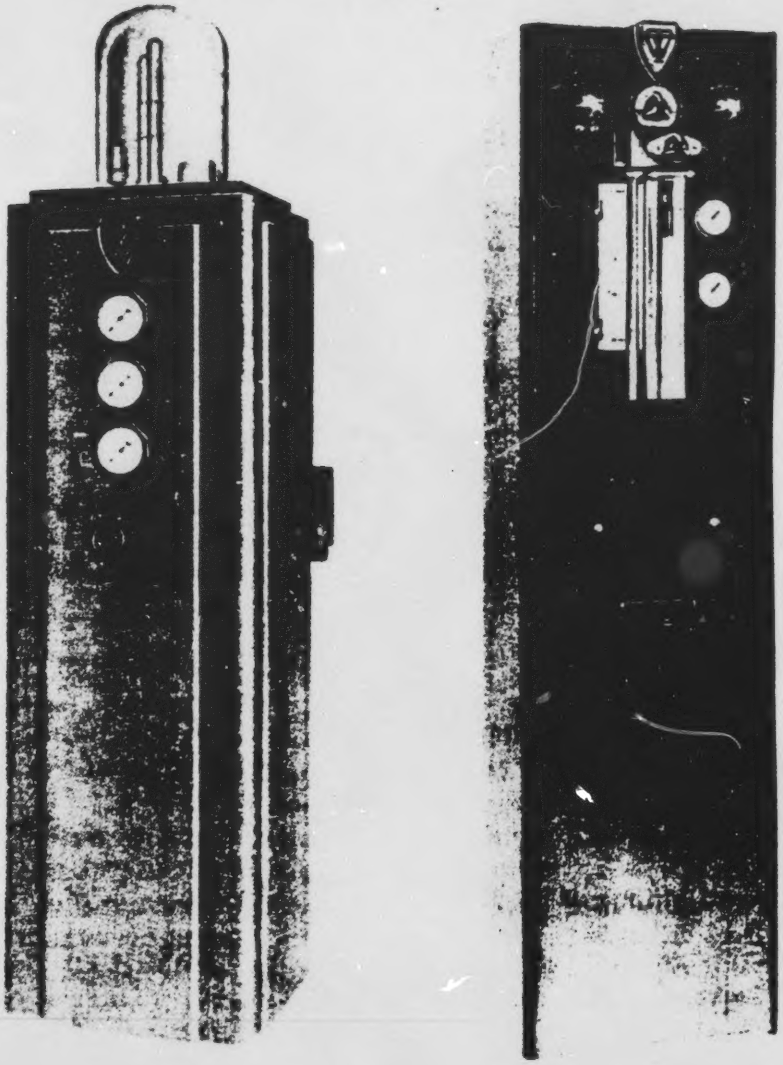

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Figure 2. Views of Vacuum Type Chlorinators: (1) Water Diaphragm; (2) Mechanical Diaphragm

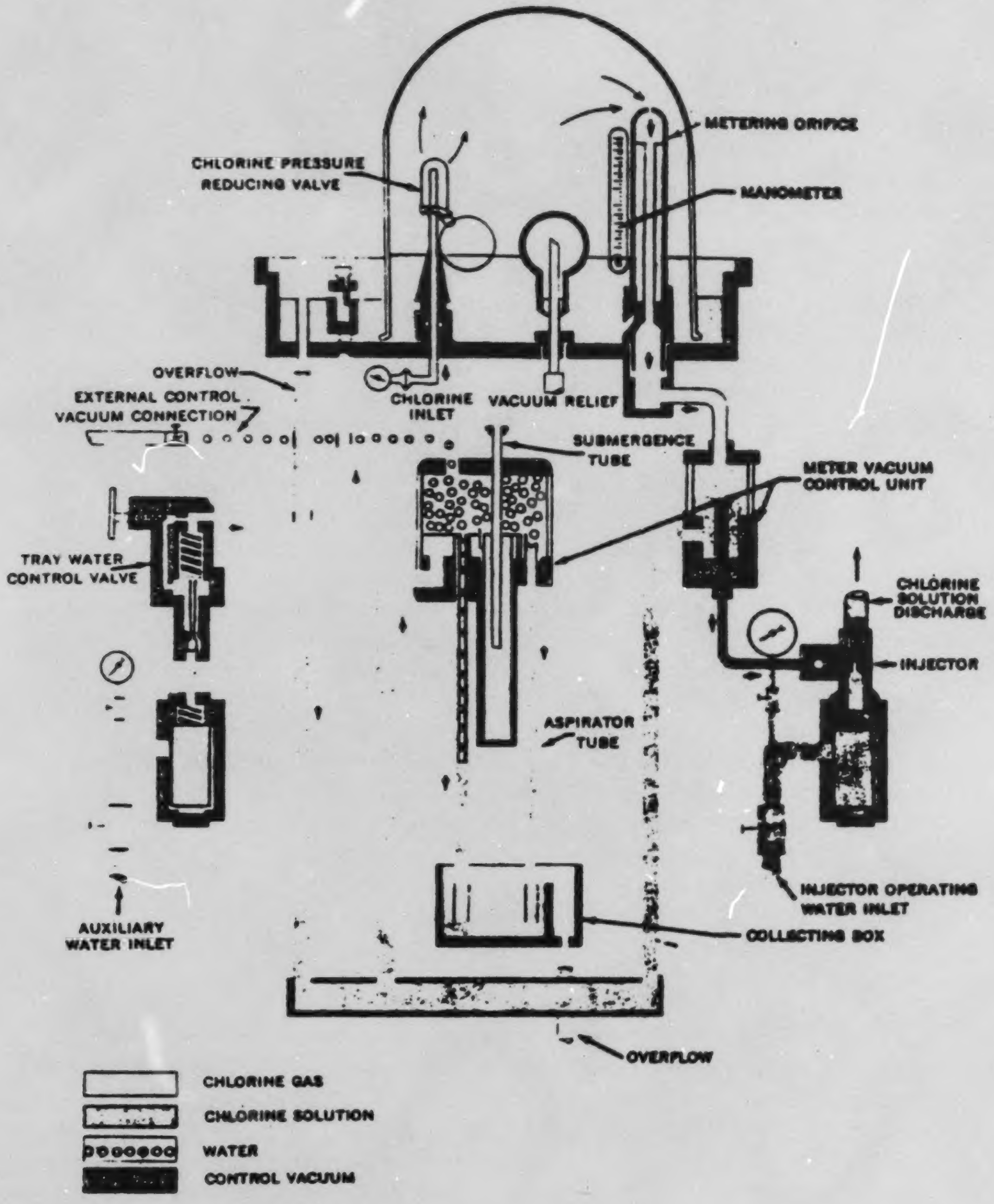

CHLORINE PRESSURE REDUCING VALVE
METERING ORIFICE
MANOMETER
OVERFLOW
EXTERNAL CONTROL VACUUM CONNECTION
CHLORINE INLET
VACUUM RELIEF
SUBMERGENCE TUBE
METER VACUUM CONTROL UNIT
TRAY WATER CONTROL VALVE
CHLORINE SOLUTION DISCHARGE
INJECTOR
ASPIRATOR TUBE
INJECTOR OPERATING WATER INLET
AUXILIARY WATER INLET
COLLECTING BOX
OVERFLOW
CHLORINE GAS
CHLORINE SOLUTION
WATER
CONTROL VACUUM

Figure 3. Flow Diagram of Vacuum Type Chlorinator-Water Diaphragm

Vacuum Type, Water Diaphragm Chlorinator manufactured by Wallace and Tiernan, Inc. (See figures 2 and 3.)

This type machine has a bell jar set in a tray of water which acts as the water diaphragm. A small quantity of water is constantly supplied to the tray to maintain the bell seal and the excess overflows to the waste. In some machines this water is supplied through a constant level box with float-controlled make-up valve. The main elements of this chlorinator are the injectors through which a water supply flows, the chlorine control valve, and the orifice meter. The injector creates a partial vacuum within the bell jar causing the water level to rise inside the jar. Chlorine gas passes from the chlorine cylinder through the chlorine pressure reducing valve and into the bell jar. The pressure reducing valve is located inside the bell jar and is controlled by a ball float which moves with the surface of the water within the bell jar. This inside water surface acts as a diaphragm which, when it lowers, causes the float-controlled valve to reduce the chlorine flow into the bell jar, and, conversely, to increase the chlorine flow when the water level rises. The bell jar is also provided with a vacuum relief valve to admit air when the chlorine supply is exhausted or fails and the water level in the jar rises. The metering orifice is also located inside the bell jar and above the water level. It controls the flow of chlorine gas to the injector where it is mixed with water to form a chlorine solution which is then mixed with water to be treated. Rate of feed is proportional to the negative pressure difference between the bell jar and meter. The amount of vacuum within the meter is controlled by the height of the adjustable suction tube, and is indicated by the rise of water in the annular space within the glass meter tube. A scale mounted on the metering tube indicates the rate of chlorine feed in pounds per 24 hours. This machine can be equipped for manual, semiautomatic or automatic operation.

The chlorine control valve and compensator are of the needle and differential diaphragm type. Gas pressure is reduced by this combination valve and compensator before metering and it maintains a constant pressure of chlorine gas against the metering orifice. The metered flow of chlorine gas is passed through the meter to the injector where it is mixed with water and the resulting chlorine solution is then mixed with the water to be treated. A vacuum relief valve is provided at the metering orifice chamber, which admits air should the chlorine gas supply become exhausted or fail. Equipment for manual, semiautomatic, or automatic operation is optional.

Vacuum Type, Mechanical Diaphragm Chlorinator Manufactured by Wallace and Tiernan, Inc. (See Figure 4.)

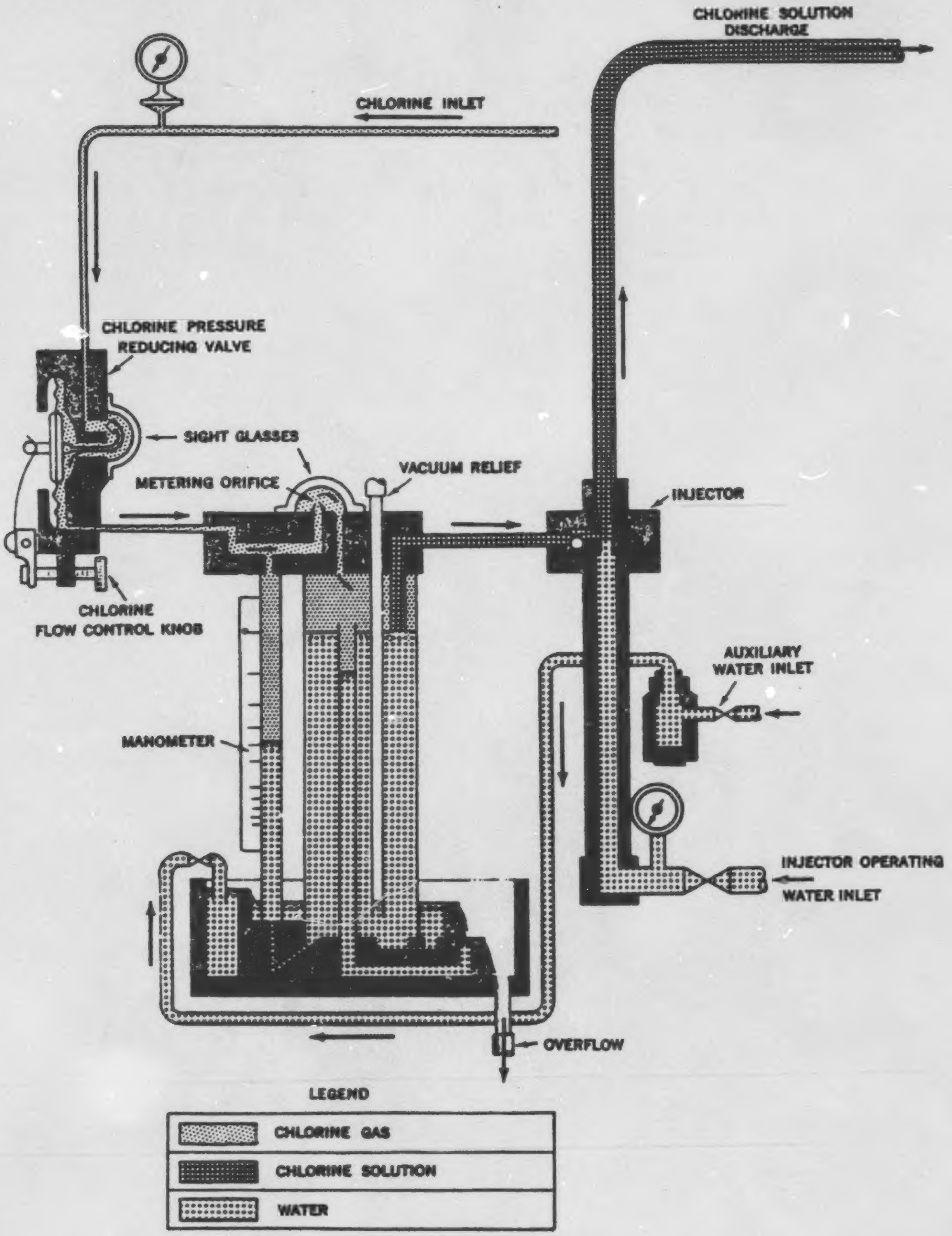

CHLORINE SOLUTION DISCHARGE
CHLORINE INLET
CHLORINE PRESSURE REDUCING VALVE
SIGHT GLASSES
METERING ORIFICE
VACUUM RELIEF
INJECTOR
CHLORINE FLOW CONTROL KNOB
AUXILIARY WATER INLET
MANOMETER
INJECTOR OPERATING WATER INLET
OVERFLOW
LEGEND
CHLORINE GAS
CHLORINE SOLUTION
WATER

Figure 4. Flow Diagram of Vacuum Type Chlorinator-Mechanical Diaphragm

Hypochlorinators

Hypochlorinators, or solution feeders, introduce chlorine into the water supply in the form of hypochlorite solution. They are usually positive displacement piston or diaphragm mechanical pumps. Selection of a feeder depends on local conditions, space requirements, water pressure conditions, and supervision available. Hypochlorinators are sometimes used as stand-by equipment for gas chlorinators. There are many makes of chemical feed equipment: (1) Proportioneers Chlor-O-Feeder is a positive displacement - diaphragm type pump, (2) Wallace and Tiernan Hypochlorinator is a positive-displacement diaphragm, and (3) Model S Hypochlorinator is a positive-displacement diaphragm pump.

Hypochlorinators are basically constructed on the same principles which employ a diaphragm, piston rod to move diaphragm, check or poppet valves, stroke adjuster, transparent plastic head, and an electric motor. See figures 5 and 6 for typical chlorinator. The operation of chlorinator or chemical feed is basically the same. The suction stroke of the diaphragm draws solution from the solution tank into the pumping chamber, through discharge tubing into the main water line. The pumping chamber has check or poppet valves on the inlet and outlet ports that open alternately with each pump stroke, thus keeping the solution moving in one

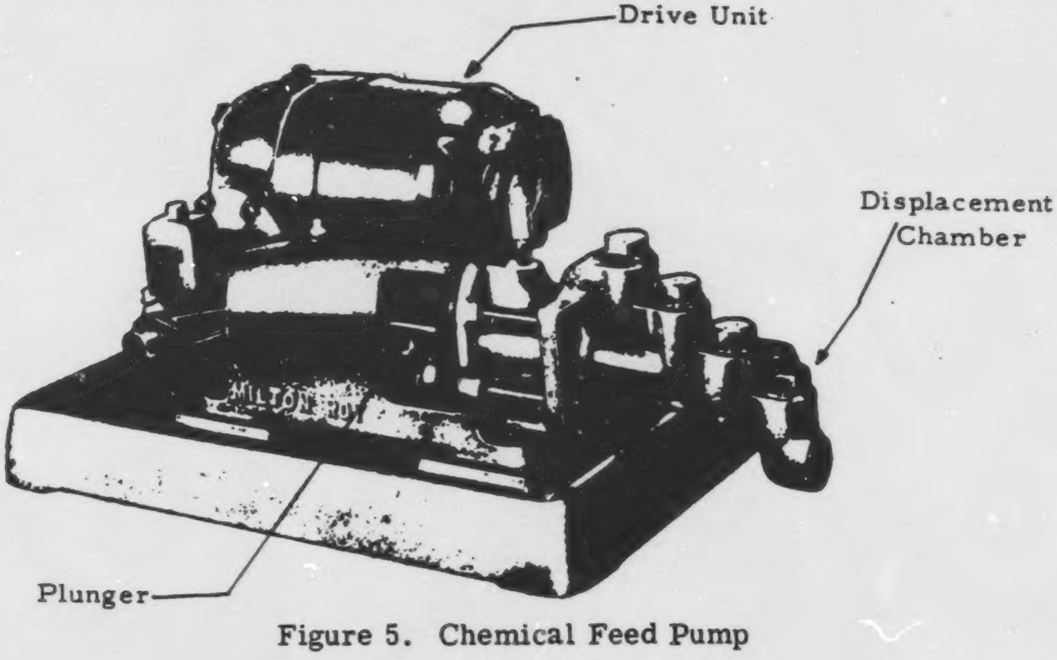


Figure 5. Chemical Feed Pump

direction only. (See figures 5 and 6.) The pumping chamber consists of a transparent plastic head that aids in visually inspecting the pump for operation. The diaphragm and poppet valves are molded from synthetic rubber.

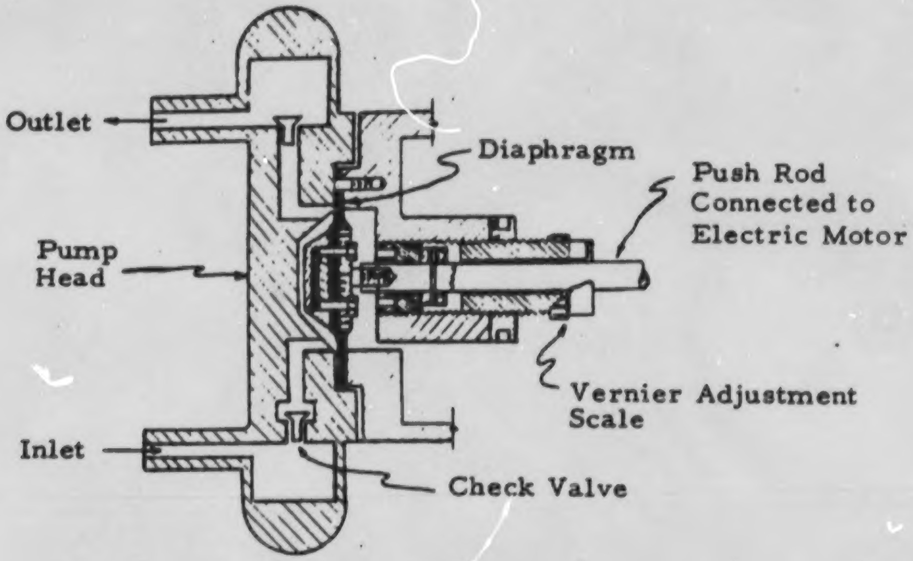


Figure 6. Cross Section of Typical Diaphragm Pump

CHLORINATION CONTROLS

Correct chlorine dosage destroys all pathogenic organisms, except certain amoebae cysts which can be removed by filtration, and provides enough residual to protect the water in the distribution system. In its flow through the distribution system, the residual is reduced by aeration in storage tanks, reaction with plant and animal life and other organic material in the system, and with slowly oxidizing substances in the water. It is therefore frequently necessary to provide an initial residual higher than minimum requirements to maintain the minimum distribution system residual.

Residual Tests

Chlorine residual tests are the basis of chlorine control. When the distribution system chlorine residual losses are relatively high, the residual required at the point of application is determined from local experience. However, this relationship changes with water temperature, quality, and rate of consumption, and with the amount of organic matter and slimes in the distribution system. Daily tests of residuals in the distribution system are therefore necessary. The amount of chlorine residual required for adequate disinfection is that which will insure the destruction of pathogenic organisms as demonstrated by bacteriological examinations.

Procedure for Performing the Chlorine Residual Test:

1. Obtain water sample.
2. Rinse the two test tubes with sample to be tested.
3. Add 0.5 ML ortho-tolidine (OTD) to one test tube.
4. Add 10 ML of sample to the other test tube.
5. Transfer the 10 ML sample to the other test tube.

   IMPORTANT: The reason for transferring the 10 ML sample to the second test tube is to permit a good mixture between the OTD and the sample, thus preventing the possibility of contamination while handling.
6. Fill second test tube with 10 ML of sample.
7. Select the proper disc and place in comparator.
8. Place the two test tubes in the comparator making certain the sample with OTD is in the right hand side of the comparator.
9. Holding the comparator to a source of light rotate the disc until a color match is made.
10. Read the chlorine content in the window of the comparator.
11. Record the chlorine content and reserve for further use.
12. Clean and store equipment to its original position.

Checking Rate of Feed

To ascertain that chlorinator is feeding the indicated amount, the cylinders are usually mounted on a platform scale. Loss in weight during the check period is observed.

$$\text{Rate of feed} = \frac{\text{Loss in weight x 24}}{\text{Check Period in Hours}} = \text{Pounds per day.}$$

Rate of feed of hypochlorinators is found from the loss in volume of gallons of solution by determining change in depth of solution in its container. Knowing the solution strength, the pounds chlorine used can be calculated. Substituting this figure in the above equation, for the loss in weight, the pounds per day rate can be determined.

CHLORINATION OPERATION AND SAFETY PRECAUTIONS

Chlorination Operation Precautions

Chlorine gas is extremely irritating to sensitive tissues of the eyes, mouth, throat, and nose. Repeated exposure to relatively low concentrations may have a cumulative effect on lung tissues. Because chlorine is heavier than air, exhaust fans are installed to draw air from the lowest point in the room. The exhaust system's blowers or fans, must have their switches readily accessible from the outside.

Chlorine is noncorrosive when dry but very corrosive when moist. Parts coming in contact with chlorine solution must be made of silver or other noble metals, tantalum, glass, rubber, or certain synthetic compounds.

Chlorine reacts with greases, oils, ethyl alcohol, and ether to produce solid compounds which clog fittings and chlorinator parts. Carbon tetrachloride is the best cleaning agent to remove these compounds. Extreme care must be taken to provide adequate ventilation while using it.

If chlorine gas is drawn off too rapidly, frost forms on cylinder and lines. Freezing retards passage of the gas. Maximum safe rates from 150 pound cylinder is 40 to 50 pounds per day and 400 pounds per day from one-ton cylinders.

Each cylinder valve is equipped with a fusible plug of an alloy designed to melt between 157° and 162°F for the purpose of releasing the contents of the cylinder in the event of fire or other exposure to high temperature.

Use a paste of freshly mixed litherage and glycerin to make up threaded joints. Support piping securely, slope piping so it drains back to cylinder.

Open chlorine valves slowly and carefully, using a wrench of proper size (not longer than six inches). Open valves only part way; one full counterclockwise turn of the valve stem permits maximum discharge.

Close valves as soon as cylinder is empty and crayon mark the cylinder with a large "E".

When a chlorine odor is noted, authorized employees will start the ventilating system, put on their gas mask, and locate the leak by holding the mount of an unstoppered bottle of ammonia water close to pipes, fittings, and valves. Ammonia vapor and chlorine gas form heavy white fumes, thus revealing the point from which chlorine is leaking. After leak is located, shut off flow of chlorine and repair leak. If cylinder head is leaking and cannot be stopped, waste the gas from the cylinder outdoors in a good wind or run it into a caustic soda solution. A solution of 25 pounds of caustic soda in ten gallons of water will absorb 20 pounds of chlorine gas.

Chlorination Safety Precautions

1. Maintain only the supply of chlorine in any chlorinator room that is sufficient for normal daily demands.

2. Allow only reliable and trained men to handle chlorine.

3. Handle containers carefully to avoid dropping or bumping them.

4. Avoid hoisting containers as much as possible; if hoisting is necessary, use safe lifting clamps.

5. Store cylinders in a cool place, away from dampness, steam lines and fire, and in an upright position, secured from tilting and falling.

6. Keep protective valve caps on containers when not in use.

7. Never connect a full cylinder to a manifold with another cylinder unless temperature of both are approximately the same.

8. When chlorine is not being drawn or is empty, keep the valves closed.

9. Disconnect valves as soon as containers are empty and check for chlorine leaks at valve outlets.

10. When chlorine leaks occur, only qualified personnel, with suitable respiratory equipment, will be assigned to investigate and correct the trouble.

11. Do not apply water to chlorine leak as it is very hazardous and results in corrosive action which will enlarge leak.

12. Never apply flame or blow torch or other direct heat to chlorine containers.

13. Temperature of a chlorinator room should be about 70°F.

14. Never ship a defective or leaky cylinder unless it is completely empty. Paint "DEFECTIVE" plainly on all such cylinders.

15. Follow all regulations on shipping, storing, and using compressed gas cylinders.

16. Never use a chlorine cylinder for any purpose other than holding chlorine gas. Do not refill cylinders.

17. Provide proper means of egress from areas where chlorine is stored or used.

18. A gas mask is provided for handling chlorine. Mask should be located near, but outside of, chlorine feeder and storage areas. A minimum of two gas masks at each chlorine feeder or storage area.

19. Administer first aid to victims as soon as they are removed from the area of the leak. If the victim is unconscious and not breathing, use the mouth-to-mouth or back pressure arm lift method of producing artificial respiration. Summon qualified medical assistance immediately.

SUMMARY

Disinfection is a necessary step in purification of water supplies. As stated before, it is almost impossible to secure a water supply free of bacteria and impurities, so man has to purify his water to make it safe for consumption. The most commonly used purification agent is chlorine. Disinfecting is the process of destroying disease producing organisms. Although chlorine is the most commonly used disinfectant, there are many other types of disinfectant agents and purification methods that can be used.

When chlorine is introduced to water, it reacts to form hypochlorous acid and hypochloric acid. It is the hypochlorous acid which actually kills micro-organisms present in water. This can be accomplished by various methods of disinfection. Chlorine can also be used in areas requiring special treatment such as amoebic cysts, schistosomiasis, swimming pools, mains, filters, wells and storage tanks.

The equipment used in the chlorination of water included both chlorinators and hypochlorinators.

It was learned that chlorine dosage must be carefully controlled and tested, and the chlorine residual test was the method most used.

It was determined that chlorine is a very dangerous chemical if not handled and controlled properly, but since it is so beneficial in water purification its advantages outweigh the disadvantages. Thus, we must exercise caution and observe the many safety precautions when working with or handling chlorine.

QUESTIONS

1. Why must water supplies be purified and disinfected before consumption?

2. Name five different types of chlorine which are available for disinfectant use.

3. Chlorine cylinders are available in what size containers?

4. HTH contains how much free available chlorine?

5. List five methods of purification or disinfectant agents which can be used to purify water.

6. What is the acid which is responsible for killing micro-organisms?

7. Define the following:

   a. Chlorine Residual

   b. Free available chlorine

   c. Combined available chlorine

   d. Chlorine dosage

   e. Chlorine demand

   f. Disinfecting time

8. The effectiveness of chlorine ______________ with rise in temperature, but is retarded with a ____________________pH.

9. What is the AFM which sets the policy for chlorination?

10. List three areas where special chlorination treatment is employed.

11. What are four methods of disinfection?

12. Name two types of equipment used in chlorination.

13. How may chlorinators generally be classified?

14. Hypochlorinators are usually of what two types of displacement?

15. What is used primarily to control chlorine in water supply systems?

16. List five operation and safety precautions.

REFERENCES

1. AFM 85-13, Maintenance and Operation of Water Plants and Systems
2. TM 5-700, Field Water Supply

TASTE, ODOR, AND COLOR CONTROL

OBJECTIVE

The purpose of this study guide is to teach you the causes and treatment of unpleasant and undesirable taste, odor, and color of water.

INTRODUCTION

Every effort should be made to provide water of excellent quality because of its effect on the health and morale of the consumer. In addition to being safe for drinking, cooking, and washing, water should be clear and free of objectional tastes and odor.

If the water supply has an unpleasant taste or odor, consumers will probably use any other available supply, whether or not it is safe. Water that is pleasing to the taste is called "palatable." However, palatable water is not always safe to drink. It was stated in an earlier lesson, water that is both safe and drinkable is termed "potable."

Information will be given under the following main topics:

- TASTE AND ODOR CONTROL
- COLOR CONTROL

This study guide will not contain all the information that you should know, therefore, additional study is recommended.

TASTE AND ODOR CONTROL

Tastes and odors are more prevalent in surface water than in ground water, and cold water has less taste and odor than warm water. The odors are usually described as aromatic, disagreeable, fishy, moldy, sweetish, and vegetable. The strength of the odor varies from very faint to very strong.

Water may also have a disagreeable taste because it contains hydrogen sulfide and free chlorine. Free chlorine may originate in the purification process. The presence of bone and fish oil is especially undesirable.

The principal cause of unpleasant taste and odor in water are: (1) Pollution by industrial wastes, such as canneries, chemical manufacturing plants, and by-products of coke plants; (2) Excessive algae growths and slime depositis; (3) Decomposition of organic matter; (4) Dissolved gases, such as hydrogen sulfide, H_2S, and (5) Iron and manganese. Depending on the causes, taste and odor can be removed by aeration or by treatment with activated carbon, copper sulphate, or chlorine. Chlorine dioxide, made by reacting sodium chlorite with chlorine, has been found effective in combating tastes and odors caused by phenolic compounds. Potassium permanganate has recently been used effectively.

Taste and odor control chemicals may be added to the raw water, during rapid mix or fluoridation, after sedimentation or prior to filtration. Some of the treatment methods will be discussed in the following paragraphs.

Aeration

Aeration consists essentially of exposing as much water surface as possible to the air. During aeration, gases dissolved in the water supply are released to the atmosphere; soluble iron salts are oxidized and become insoluble so they can be removed by settling. Aeration raises the pH by eliminating dissolved carbon dioxide but increases corrosiveness by increasing the amount of dissolved oxygen. Methods of aeration include spraying water up over a shallow receiving basin, and forcing air into a basin with diffusers or mechanical pump type aerators.

Activated Carbon

Activated carbon is specially treated granular or powdered carbon which, because of its increased surface area, will absorb larger quantities of dissolved gases, liquids, and finely divided solids than ordinary carbon. It is highly effective in taste and odor control, provided that the type of activated carbon used meets required standards, the dosage is correct, the carbon is mixed intimately with the water, and the carbon is in contact with the water for an adequate period of time.

Because of the wide range in waters, no general rule can be given for activated carbon dosage. The dose required at each plant must be determined by periodic laboratory tests. A carbon dose of 3 ppm removes most tastes and odors from water. However, if the tastes and odors are caused by pollution from industrial wastes, the dose may have to be increased to 8 ppm, or even 20 ppm at times.

Activated carbon may be applied to water at one or more points depending on results desired. Usually, carbon is added at one of the following points: (1) in raw water, (2) in mixing basin, (3) in treatment plants, (4) split feed, (5) in filters, and (6) with chlorine.

Copper Sulfate

Copper sulfate is sometimes used at a surface water source where the tastes and odors are caused by small organisms living in the lake or reservoir. It may be applied by spraying a solution over the water surface or allowing crystals in a porous sack to dissolve. Because copper sulfate kills fish, its use is limited. Concentrations that kill common varieties of fish are listed below in pounds of copper sulfate per million gallons of soft water. Total concentrations are considerably higher in hard water.

Trout	1.2
Catfish	2.5
Suckers	2.5
Carp	2.5
Pickerel	3.5
Black Bass	17.0
Goldfish	4.0
Perch	6.0

Chlorine

Chlorine dosage at the plant of 0.3 to 1 ppm destroys most algae but may intensity tastes and odors. The break-point method of chlorination requires higher dosages but eliminates taste and odor as well as algae.

Potassium Permanganate

Potassium permanganate has shown great possibilities as a taste and odor treatment, and for serious problems, it is very economical. It does not combine with the substances causing taste and odor, but works as an oxidizing agent so there seems to be no possibility of intensifying or "setting" taste and odor. Experience indicates that permanganate is not a "cure-all". The residual manganese dioxide is insoluble, is absorbent, assists the coagulation process and is removed by coagulation and filtration. When the raw water carbon demand is 2 ppm or less, carbon is more economical than potassium permanganate.

COLOR CONTROL

Color in natural waters is caused mainly by vegetable dyes or by excessive amounts of iron and manganese. Minerals contained in industrial wastes may also cause color. The coloration is usaully caused by colloidal matter and may be removed in the same manner as other colloids, by chemical precipitation, coagulation or absorption, followed by filtration.

No one method will remove all colors and no rule will apply to all waters. Color removal requires trial of the following methods to determine which is most efficient and economical in the particular case.

Alum Coagulation

Coagulation with alum, followed by lime or soda ash if necessary, and filtration is the most common method. The alum must be added first and given some reaction time at a pH of 5.5 to 6.0 before adding the alkali. If the alkali is added first, it will "set" the colors and prevent removal.

Chlorination

Color removal by chlorination requires a dosage of 1.0 to 10.0 ppm, the correct amount being determined by trial. A detention or contact time of at least 15 minutes is necessary and not less than 0.1 free or combined residual should be maintained.

Chlorinated Copperas

The addition of chlorinated copperas at a low pH with an alum dose applied halfway through the coagulation basin has been very successful in some instances. Dosage has to be determined by trial.

Activated Carbon

Some color is susceptible to removal with activated carbon. The colloidal matter is absorbed by carbon atoms with free valences and is removed by sedimentation and filtration. Tests of carbon applied to the particular water is the only method of determining the effect of carbon for color removal.

Control Test

See LAB Manual for 563X0 Water Courses.

SUMMARY

Water that is to be used for human consumption should be free from taste, odor, and color. Taste and odor in water are generally caused by industrial waste pollution, algae growth, organic matter, dissolved gases, iron and manganese.

The color in water is usually caused by colloids, by chemical precipitation, coagulation or absorption, followed by filtration.

QUESTIONS

1. What is meant by "palatable" water?
2. What is meant by "potable" water?
3. List at least three water odor descriptions.
4. Give three methods of treatment for water taste and odor control.
5. What is the limiting factor in the use of copper sulfate for water treatment?
6. What causes color in natural waters?
7. What is the range required for chlorine to destroy most algae?

REFERENCE

AFM 85-13, Maintenance and Operation of Water Plants and Systems
"Water Supply and Treatment", National Lime Association

FLUORIDATION AND DEFLUORIDATION OF WATER

OBJECTIVE

The objective of this study guide is to aid you in learning the purpose of fluoridation, fluoride compounds used, equipment used, point of application, dosage, testing, defluoridation, and safety precautions.

INTRODUCTION

In recent years statistical studies have been made showing that where naturally occurring fluorides were present in appreciable amounts, indicated tooth decay among the residents was surprisingly low, especially among children and young adults. This condition generally held throughout their life span. Subsequent large scale experimentation in certain cities of the United States indicated that where fluoride dosages were applied in controlled optimal amount of about 1.0 ppm to the water supply, cavities in children were reduced from 40 to 60 percent. Installation for the application of fluorine (either in the form of fluorides such as sodium fluoride, or of acids such as hydrofluosilic acid) must have the approval of the Surgeon General, U.S. Air Force.

This information will be discussed under the following main topics:

- FLUORIDE COMPOUNDS
- EQUIPMENT
- APPLICATION
- DOSAGE
- SAMPLING AND TESTING
- DEFLUORIDATION
- SAFETY PRECAUTIONS

This study guide will not contain all the information you will need to know; therefore, the study of additional material is recommended. The additional study material is listed at the end of this study guide.

FLUORIDE COMPOUNDS

There are three fluoride compounds commonly used in fluoridation. They are sodium fluoride (NaF), sodium silicofluoride (Na_2SiF_6), and hydrofluosilicic acid (H_2SiF_6). The first two are dry, white, crystalline salts in powder form, and the last is a corrosive liquid. All are toxic chemicals and must be handled with extreme care, from the standpoint of both bodily contact and inhalation of dust if in powder form.

The powder chemicals are generally packaged in 100-pound paper bags or 350-400 pound fiber board drums; acids are usually obtained in 100-pound or 55-gallon rubber lined steel drums.

Store all chemicals in a dry room convenient to feed equipment. To protect chemicals from damage, place packages, including steel drums, on boards or grids to permit air circulation to prevent moisture forming on the container bottom. Hopper filling openings should be at a suitable height to avoid the use of ladders and platforms.

EQUIPMENT

Fluorides are proportion fed into water either as liquids or solids. Chemical feeders can be broadly divided into two types: solution feeders, which are essentially small pumps, used to feed a carefully measured quantity of accurately prepared fluoride solution (hydrofluosilicic acid) during a specific time, and dry feeders which deliver a predetermined quantity of the solid material during a given time. Dry feeders can be further divided by types depending on the method of controlling the rate of feed. Volumetric dry feeders deliver a predetermined volume of dry chemical within a given time; gravimetric feeders (loss in weight) deliver a predetermined measured weight of chemical within a given period.

Volumetric feeders (Figure 1) will deliver as little as three to four ounces per hour to treat supplies of 200,000 gallons or more daily. Gravimetric feeders (Figure 2) will feed as little as one pound per hour but are generally used to treat supplies of five million gallons or more daily.

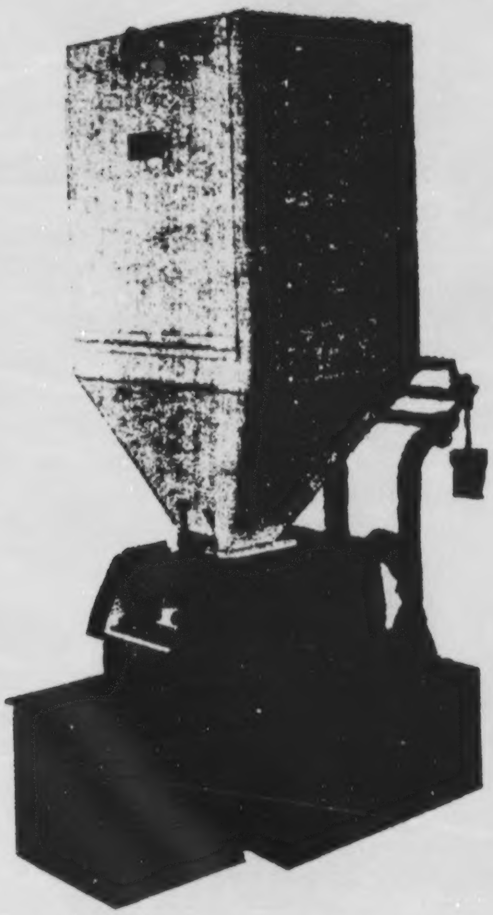


Figure 1. Volumetric Feeders

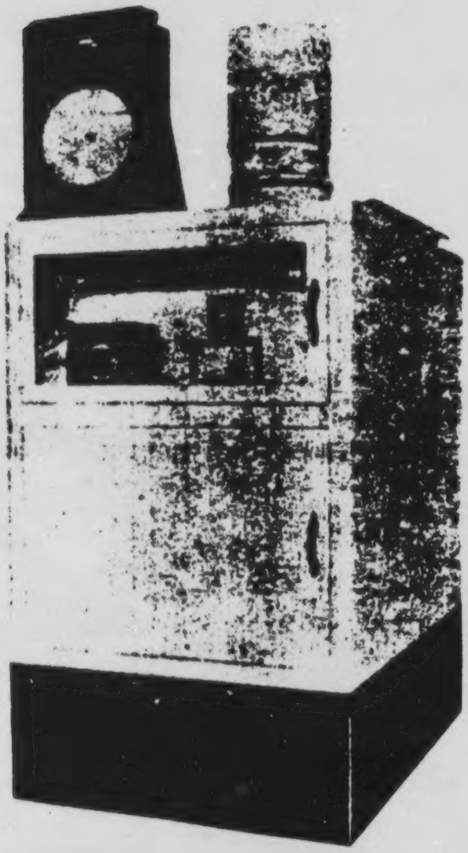


Figure 2. Gravimetric Feeders

Volumetric Type Dry Feeder

The maximum rate of feed for the machine at any Air Force plant should not exceed 12 pounds per hour and the hopper should hold at least 100 pounds but not more than 200 pounds of chemical. The hopper should be equipped with an agitator to prevent arching and assure a continuous chemical feed at all times. The feeder must feed the chemical uniformly. Rate adjustment apparatus permits precise adjustment of the feeding rate. Feeding mechanism must be completely inclosed to prevent any escape of dust. It is advisable to provide as an integral part of the feeder a weighing device or a platform scale and a loss in weight indicator-recorder which will continuously indicate and record the weight of chemicals in the hopper. The solution chamber must be completely resistant to corrosion, and provide a removable cover and a dust tight flexible connection to the feeding mechanism. The volume of the solution chamber (dissolver) should be at least one gallon per pound of sodium fluoride fed per hour at maximum rate of feed. For sodium silicofluoride, the volume should be at least five gallons per pound fed per hour. Regardless of the chemical feed rate, the volume of the dissolver should exceed 10 gallons.

Gravimetric Loss In-Weight Type Dry Feeder

This feeder differs from the volumetric in that, instead of displacing a preset volume of chemical, a definite weight of the chemical is displaced. A higher degree of accuracy is obtained. The scales, hopper, all the mechanism, and the dissolver or solution chamber should be inclosed. A totalizer should show the total amount of chemical fed, in pounds, on a direct reading counter without the use of multipliers. The accuracy of the totalizer should be better than 99 percent. The hopper capacity and scale beam capacity should not exceed 250 pounds.

Proportioning Pumps

At installation where water is purchased and fluoridation is desired, arrangements can be made with the contractor to fluoridate water supplies. Where the source of water is from wells pumping to a central point a proportioning pump may be installed to inject fluoride. Where wells are not pumping to a central point a proportioning pump must be provided for each well. The most commonly used solution feeders are positive displacement diaphragm pumps with feeding heads constructed of polyvinyl or methyl methacrylate plastic and neoprene, which are resistant to fluoride chemicals.

For these installations the most accurate and economical method of fluoridation is by the application of sodium fluoride solutions of less than four percent. For the preparation of solutions less than saturated (four percent), a weighted amount of the chemical is added to a definite weight or volume of water and the mixture is mechanically or manually stirred until a homogenous solution exists. Often two reagent tanks are used, one tank being prepared while the other is in use. Each tank should have sufficient volumetric capacity to hold a 30 hours' supply of reagent. For testing and measuring purposes the reagent tank should have a scale attached to the inside that can be read by the operator. A sight glass may be installed. Water used for making sodium fluoride solutions is zeolite softened or treated with sequestering agent such as calgon, nalco 918, or equivalent where the total hardness exceeds 100 ppm expressed as calcium carbonate.

APPLICATION

In feeding fluorides it is not necessary to allow for a contact period as with chlorination. Water has no "fluoride demand", hence the entire quantity can be accounted for in the distribution system unless it is lost through treatment processes. Ordinary filtration occasions a loss of 0.1 to 0.3 ppm of the fluoride added. The most desirable point of application is in the filter effluent or at the entrance to the clear well. At installations using well water the solution is normally injected into the discharge from the well pumps unless water is discharged to a central point of storage. Fluoride chemicals are added after all other chemicals have had an opportunity to react, but prior to final chlorination.

DOSAGE

In fluoridation practice the target residual in the distribution system is prescribed for each installation by the Surgeon General. In general the spread is from 0.7 to 1.2 ppm fluoride in the finished water supply, the average being about 1.0 ppm, to determine the dosage that will give a residual of 1.0 ppm, the natural fluoride content of the raw water must be considered. Chemical dosage must be set and supervised by properly authorized personnel. Over-all dosage checks are made at least daily. Continuous observation of the equipment is a daily routine operation. Hourly checks reflect any dosage variations and provide a basis for regulation of overfeed or underfeed.

SAMPLING AND TESTING

Sampling

Representative composite samples from the treatment plant effluent are collected and analyzed daily in addition to the dosage checks for plant controls. Sampling from representative points in the distribution system are performed at least weekly and preferably twice a week as a further means of evaluating the effectiveness of plant control.

Testing

Chemical analysis will be in accordance with methods in "Standard Methods for the Examination of Water, Sewage and Industrial Wastes". For plant control, analysis may be by colorimetic methods. If plant laboratory control is not available at an installation, samples may be shipped to a designated laboratory for analysis.

DEFLUORIDATION

Methods for the removal of excessive fluorides from water were made available soon after it was discovered that excessive fluorides contributed to fluorosis. Youths continuously exposed to water containing about 5 ppm or more fluoride are invariably afflicted with mottled enamel of the permanent teeth, many of these youths eventually lose their teeth through attrition.

At present, there are three methods of defluoridation which have proved practicable for the removal of excess fluorides. These methods involve the use of activated alumina, bone char, or magnesium compounds. The activated alumina and bone char employ an insoluble granular media which remove the fluorides as water filters through them. They are periodically regenerated as they become saturated with the fluorides, this is accomplished by chemical treatment. The use of magnesium compounds to remove fluorides are employed so that they are removed with magnesium which might be added in the form of lime. They are subsequently removed through the use of settling basins and then discarded.

SAFETY PRECAUTIONS

Water plant operators who handle fluoride compounds must be trained to protect themselves from hazardous accidental exposures. Fluoride dust may cause irritation of the skin and mucous membrane.

All water plant operators should be fully orientated on the following safety rules:

1. Breathing of fluoride dust should be avoided. In case of spillage, clean up immediately.
2. Wear rubberized gloves, plastic or rubber aprons and masks when exposed to the dust.
3. Dust must be removed immediately from the skin by bathing or washing.
4. Rubber gloves, rubber boots, and acid proof aprons are required for the handling of Hydrofluosilic acid. After using equipment it should be washed thoroughly.
5. Personnel with open cuts or sores should NOT be allowed to handle fluoride dust or acids.
6. Detailed instructions on handling and safety precautions to be taken will be posted at the point of operation and adequately enforced.
7. All fluoride containers must be labeled with a sign warning that a poison is contained therein.
8. Containers are disposed of by incineration or burying in the sanitary fill.
9. When handling hydrofluosilic acid, care should be exercised not to spill it on the body or clothing, should this happen, wash and flush immediately.
10. First Aid:
    a. Should internal poisoning occur the patient should immediately drink, either, a one percent solution of calcium chloride, a glass of lime water (saturated solution of calcium hydroxide), or a large amount of milk.

    b. For external injuries wash the area with a large amount of water.

c. Should chemicals affect or enter eyes, flush immediately with warm water.

d. In all events of injury and poisoning immediately seek medical aid.

SUMMARY

In this study guide you learned that a controlled amount of fluoride in water supplies can be beneficial to the populace, and that too much could be harmful. The fluoride residual for each installation is prescribed by the Surgeon General. The residual spread is from 0.7 to 1.2 ppm with an average of 1.0 ppm.

The three most commonly used fluoride compounds are sodium fluoride, hydrofluosilic acid, and sodium silicofluoride. They are available in 100, 350, and 400 pound containers and 55 gallon drums.

Storage should be in a dry room, and close to feed equipment. Containers should be stored on platform allowing air circulation to prevent moisture from forming on bottom of containers. Hopper filler openings should be at the proper level to avoid the use of ladders.

The equipment used to feed fluroide into water is proportioning pumps or dry feeders. The proportioneer pumps feed a carefully measured quantity of solution during a specific time. Dry feeders can be divided into volumetric or gravimetric loss-in-weight. The volumetric delivers a predetermined volume of dry chemical in a given time and the gravimetric delivers a predetermined measured weight in a given time.

Fluoride is added after all other chemicals have had an opportunity to react, but before final chlorination.

The practice of defluoridation is the removal of excess fluorides from a water supply. This can be accomplished by three methods which involve activated alumina, bone char or magnesium. The first remove fluoride as they pass through a granular media. In the last method the fluoride is removed after sedimentation in a settling basin.

Fluoride compounds are very toxic and extreme care must be exercised when working with them.

QUESTIONS

1. Name three fluoride compounds used in fluoridation and chemical formulas.
2. Powder fluorides are supplied in what size containers?

3. Liquid fluorides are available in what size containers?

4. Why are chemicals stored on raised platforms?

5. What is the difference between volumetric and gravimetric dry feeders?

6. How are proportioneer pumps designed to feed fluorides?

7. Where are fluorides injected to a water supply?

8. What is the average fluoride residual?

9. How is a fluoride residual determined?

10. List five safety precautions while handling or working with fluorides?

REFERENCES

1. AFM 85-13, Maintenance and Operation of Water Plants and Systems

2. Manual of Water Fluoridation Practice, U. S. Public Health Service

3. Water Supply and Treatment, National Lime Association

WATER DISTRIBUTION SYSTEM

OBJECTIVE

The purpose of this study guide is to acquaint you with the water distribution system.

INTRODUCTION

The term water distribution system is applied to the parts that make up the system. The elements and parts are wells, pumps, booster stations, valves, hydrants, and reservoirs. The system must deliver sufficient water to provide required fire flow to all points. The subjects will be covered under the following main topics:

- WATER DISTRIBUTION SYSTEM
- COMPONENTS

This study guide will not contain all the information that you need to know, therefore, study of additional information is recommended.

WATER DISTRIBUTION SYSTEM

Where distribution systems are carefully planned; the pipes are usually laid out in a grid or belt system. A network of large pipes divides the base into areas; the streets within each area are served by smaller pipes connected to the larger ones. Whenever possible, the system should be planned so it will contain loops and no dead end pipes. In this way, water can flow to any point in the system from two or more directions. It should also be designed so it may be enlarged later.

COMPONENTS

The components in a distribution system start from the point where it is obtained, stored, or treated, to the points where it is used. If water is obtained from a well and chemicals added at the well, the distribution system would include the components from the well to the user.

If the water is pumped to a treatment plant, the system would start at the discharge side of the plant.

Pumps

Pumps may be required at Air Force installations to pump water from a lake, reservoir, or river to a water treatment plant. After treatment, additional pumping may be required to force water into the mains and storage facilities. In the distribution system, booster pumps may be needed to increase water pressure. At many Air Force installations, water is pumped from the source and into the mains and storage tanks in one pumping operation. Emergency pumps are needed during water supply breakdowns, or to satisfy fire fighting requirements.

Mains and Piping

Mains and piping are composed of feeder mains, distribution mains, lateral lines, and service lines. The feeder mains will supply distribution mains and storage tanks. Distribution mains are the pipe lines which make up the distribution system and include any feeder mains from which service lines take their supply. Service lines will transport the water from the distribution mains to the various buildings and facilities. The lateral lines will make the distribution system more effective and efficient by forming a closed loop system.

Storage Tanks

Water demand on an Air Force installation will vary between night and day and for different days in the week. Also, fire fighting requirements can place an excessive demand on the system at any particular time. The capacity of the distribution system most likely will not be sufficient to meet peak demands. This problem is met by placing storage tanks within the distribution system. Elevated storage tanks will also aid in maintaining the desired water pressure within the distribution system. Storage tanks are made up of four types: (1) elevated, (2) ground, (3) pneumatic, and (4) emergency.

Valves and Hydrants

Valves and Hydrants are used to control the flow of water in a water distribution system. These components will include such units as: (1) gate valves, (2) pressure reducing valves, (3) check valves, (4) curb service valves, (5) fire hydrants, and (6) globe valves. Gate valves will isolate the water supply for repair purposes. Pipes in a water distribution system can and do break. Breaks or leaks may be caused by freezing, fire, ground movement, explosion, excessive water pressure, and by collision of a foreign object. The gate valves will be closed after a break in the water distribution system; therefore, the disruption in service will affect only a small portion of the system rather than the whole distribution system.

Gate valves are placed in the distribution system so the flow of water may be shut off if a line breaks.

Globe valves are used in the distribution system on small lines or service lines. They restrict the flow and cannot be used where flow restriction is not needed.

Check valves will prevent reversal of water flow due to loss of pressure. Check valves will also isolate certain sections of the distribution system.

Pressure-reducing valves throttle the flow in pipes to reduce the pressure on the discharge side and keep it constant. They are used for feeding water from a high-pressure to a low-pressure system. If great variations in flow rates are expected, different sizes of pressure reducing valves will be installed in batteries. The valves would be adjusted so that they come into operation in order of smallest to largest as flow rate increases.

Curb service valves control water distribution to individual buildings or dwellings. These will be used as the need for water to the buildings is determined.

Fire hydrants will be placed in all areas where there is a need for fire protection. Proper operation and use of hydrants is essential to water distribution economy and safety.

With the exception of the fire hydrants and some storage tanks, the water distribution system is underground. This is more feasible to protect the distribution system from the weather. Since it is more practical to bury a large portion of the distribution system, complete maps and records must be kept showing the location of components. The water specialist should never keep a "mental map or picture" of the system, but should put all the information on record. Records and maps must be evaluated periodically. The location of buried water components does NOT change, but memories of men do.

Special valves are put in the system for various reasons, such as, pressure check, air relief, attitude, backflow prevention, etc.

Booster stations pump from a relatively low pressure feeder main to the distribution system. They may be installed at the end of a long supply line to boost the pressure for the whole installation system or may serve a portion of the installation system that is at a higher elevation than the rest.

Low-lift stations pump water from a surface supply to the inlet of a filtration, aeration, or other nonpressure treatment plant.

High-lift stations pump from gravity storage or other nonpressured source into the distribution system or through a pressure treatment plant.

Well pumps include all types of pumps used to obtain water from wells. They may discharge directly to the distribution system, to storage, or to a treatment plant.

SUMMARY

The water required to support a modern Air Force or other military unit must be palatable and potable for human consumption and personal use. Modern machinery also requires great quantities of water. "Good" drinking water may contain enough minerals to damage machines.

Safe and satisfactory water supplies to meet modern requirements are not acquired by waving a "witching stick" or by rubbing an "Aladdin's Lamp." It requires the careful work of a trained operator.

In areas of seemingly plentiful water supply, the readily available sources may be quite easily contaminated, either by an enemy (pollution, poisoning, etc.), or by unavoidable natural impurities (minerals, silt, etc.).

In areas of limited supply, extensive reconnaissance and development must be done to assure an adequate quantity.

It should be assumed that most water must be analyzed and treated properly before it fully meets the quality requirements for human consumption, personal use, and the standards required for modern machinery.

Water testing and treatment will vary from simple "cookbook" chemical procedures to extensive laboratory procedures and technical treatment methods.

The personnel assigned to locate, treat, and supply water for military uses must be resourceful and dependable. Seldom will a graduate chemist be available for performing this AFSC, but the training offered in this course can help a water and waste specialist to do the job when the need arises.

QUESTIONS

1. What is the purpose of the low-lift pumping station?
2. How are high-lift pumping stations used?
3. What is the most critical factor in planning an Air Force storage and distribution system?
4. What is the purpose of the water distribution system?
5. Name five types of components within the water distribution system?
6. Why are storage tanks necessary in a water distribution system?
7. Why is it necessary to keep an exact record of the location and maintenance of components within the water distribution system?

REFERENCES

1. AFM 85-13, Maintenance and Operation of Water Plants and Systems
2. AFM 88-10, Water Supply, Water Sources

INTERNAL CORROSION AND SCALE

OBJECTIVE

The purpose of this study guide is to aid you in becoming familiar with the causes and related problems of scale formation and corrosion in water and sewage systems.

INTRODUCTION

The term "scale," as used here, refers to the white, crusty matter formed by the crystallization of dissolved mineral matter contained in untreated or lime-softened waters. Scale can cause clogging of pipelines which may cause your system to be shut down.

The corrosion process is an electrochemical reaction in which metal deteriorates or is destroyed by an unfavorable environment. Almost everyone is familiar with rust, which is the visible indication that corrosion has attacked iron or steel parts.

Scale and corrosion will be discussed under the following headings:

- TYPES, EFFECTS, AND PREVENTION OF SCALE
- CAUSE AND PREVENTION OF CORROSION

This study guide will not contain all of the information that you will need to know and the study of additional material is recommended.

TYPES, EFFECTS, AND PREVENTION OF SCALE

Most of the scale formed in water systems is similar in appearance; however, there are several distinct types of scale. Among the most common are (1) pure mineral scale, (2) mixed scale and corrosion products, and (3) combination of minerals.

1. Pure mineral scale, such as $CaCO_3$ and $CaSO_4$. Calcium carbonate forms a loose sludge-like deposit that will crumble rather easily when dried. Calcium sulfate forms a hard adherent type of scale which is espeically objectionable in boilers.
2. Mixed scale and corrosion products. Hot water pipes are often found containing layers of rust sandwiched in between layers of mineral scale.
3. Combinations of minerals cemented together by binders, such as silica. Such combinations will produce a hard "baked-on" type of scale on hot boiler surfaces.

Scale is an undesirable formation, having the following adverse effects:

1. Reduces the safety factors by clogging the safety valves and gauge lines.
2. Clogs pipes, thus reducing carrying capacity. Pipes should be cleaned, if possible, rather than replaced. Once the scale has been removed, a chemical treatment should be used to prevent new formation.
3. Reduces operating efficiency of heating and cooling systems by clogging coils, heat exchangers, and radiators.
4. Reduces rate of heat transfer in boilers.
5. Increases cost of operation by adding to cost of maintenance and replacement.

Cause of Scale Formation

Most scale problems occur in water systems in which the water has been heated. In fact, the formation of scale or sludge deposits on boiler heating surfaces is the most serious water problem encountered in steam generation.

Most scale results from the precipitation of the minerals causing hardness in water. This may occur because the two water soluble minerals $Ca(HCO_3)_2$ and $MgCO_3$, which are the most common forms of hardness to be present in high concentrations, decompose when heated to form $CaCO_3$ and $Mg(OH)_2$. The latter compounds are only slightly soluble.

1. $Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 + CO_2 + H_2O$
2. $MgCO_3 + H_2O \xrightarrow{\Delta} Mg(OH)_2 + CO_2$

As might be expected, the slightly soluble $CaCO_3$ and $Mg(OH)_2$ precipitate and tend to settle out. Unless this material is removed by blow-down while in a soft, sludge-like condition, it will harden in place as scale.

Some scale is caused by minerals becoming less soluble in hot water than they were in cold water. Thus, water containing relatively small amounts of hardness may become supersaturated in only the thin film of water in contact with the hot boiler metal surface and leave a scale deposit which gradually accumulates and thickens. Note that scale always accumulates in the hottest part of the system.

Control and Prevention of Scale

The most effective methods for the prevention of scale formation would include one or a combination of the following treatments:

1. Pretreatment of all make-up water
   a. Turbid or muddy water must have all of the suspended solids removed. This is normally accomplished by the addition of a chemical coagulant, followed by sedimentation and filtration.

b. Softening of make-up water - all hardness may be removed from water by the ion exchange process by passing the water through a sodium cation exchanger.

All but 30 to 50 p.p.m. of the hardness may be removed from water by chemical treatment with lime (for water containing temporary hardness only) or by lime and soda ash (for water containing both temporary and permanent hardness) followed by sedimentation and filtration.

c. Scale formation in distribution systems may be prevented by stabilization of the scale forming dissolved solids contained in the water by:

(1) Addition of 2 to 4 p.p.m. of polyphosphates

OR

(2) Recarbonation (addition of CO_2 to lime-softened water)

$$CaCO_3 + CO_2 + H_2 \dashrightarrow Ca(HCO_3)2$$

Note, stabilization would not be an effective treatment for prevention of boiler scale.

(3) Addition of sulfuric acid (H_2SO_4) to cooling tower water. The addition of sulfuric acid converts the $CaCO_3$ into the more soluble $CaSO_4$.

(2) By "bleed-off" of cooling tower water and by "blow-down" of boiler water. These procedures hold down the "Cycles of Concentration" and prevent an excessive build-up of dissolved solids.

CAUSE AND PREVENTION OF CORROSION

Note that the information included in this portion of this study guide will be limited to the corrosion of internal surfaces of equipment containing water.

Since the mechanics of the electrochemical corrosion process will be discussed at greater length in Block V, it will suffice to say here that the essential requirements for electrochemical corrosion to occur are:

1. An anode (or anodic area)
2. A cathode (or cathodic area)
3. An electrolyte
4. Metal bond (path for electron flow)
5. Plenty of dissolved oxygen in the electrolyte.

Since these are "essential" requirements, corrosion may be prevented by eliminating any one of the requirements.

One area where corrosion is a constant problem concerns boilers and condensate return systems for boilers. The corrosion affecting boilers is largely caused by dissolved oxygen in the boiler feed water. Here the corrosion may be prevented by mechanical removal of the oxygen by using a deaerating heater to drive off the oxygen before it is carried into the boiler - followed by a chemical oxygen scavenger in the boiler.

The corrosion in the condensate return lines is almost always caused by dissolved gases - oxygen or carbon dioxide, and sometimes both at the same time. The dissolved oxygen originates in the boiler feedwater. The carbon dioxide comes mostly from the breaking down of bicarbonates in the boiler water.

$$\mathrm{Ca(HCO_3)_2} \xrightarrow{\Delta} \mathrm{CaCO_3 + CO_2 + H_2O}$$

The CO_2 is carried from the boiler with the steam. When the steam condenses to water, the following reaction takes place:

$$\mathrm{CO_2 + H_2O} \rightleftharpoons \mathrm{H_2CO_3}\ \text{(carbonic acid)}$$

Carbonic acid is an unstable but corrosive acid.

The corrosion attack is more severe when the two gases are both present in the condensate than when either one is present by itself. Oxygen will cause severe pitting and/or rust deposits on all the inside surfaces of the pipe (see figure 1). Carbon dioxide causes grooves or channels in the bottom of the pipe (the only part containing water) with the surface left clean and free of rust (see figure 2).

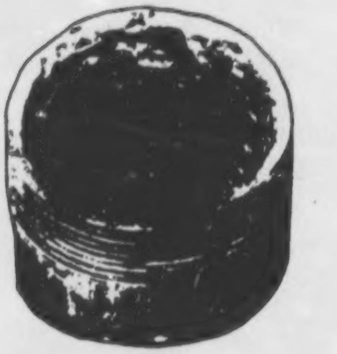
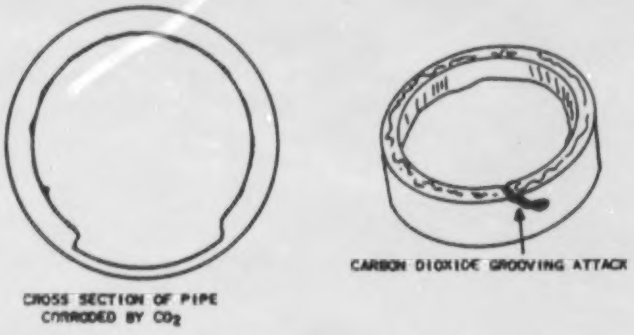


Figure 1. Oxygen Pitting



CROSS SECTION OF PIPE CORRODED BY CO2
CARBON DIOXIDE GROOVING ATTACK

Figure 2. Carbonic Acid Attack

The most successful method for the prevention of corrosion of internal or waterside surfaces of equipment through which water is being circulated consists in the addition of different chemical compounds. Among the most frequently used compounds, and their intended purposes are:

1. Sodium sulfite - Na_2SO_3 which is added to boilers and sometimes to closed recirculating water systems as an oxygen scavenger.

$$Na_2SO_3 + 1/2O_2 \longrightarrow Na_2SO_4$$

Where sodium is being used in a system, it is customary to maintain a 20- to 40-p.p.m. residual. This insures that there is no dissolved oxygen remaining in the water, and without oxygen in the water, no corrosion can occur.

2. Neutralizing amine compounds - The neutralizing amines are alkaline compounds which may be added directly to the boiler water where they volatilize (change from a liquid into a gas) and are carried from the boiler with the steam. They will return with the condensate and will be reused. The alkalinity of the amines raises the pH of the condensate. When the pH of the condensate is kept just on the alkaline side (pH of 7.0 to 7.5), there will be very little corrosion caused by CO_2 in the condensate return system. Cyclohexylamine and morpholide are brand names of neutralizing amine compounds. The control for neutralizing amines is to maintain a minimum feed that will keep the pH of the condensate between 7.0 and 7.5.

3. Filming amine compounds - The filming amine compounds are sometimes added directly to boiler steam line where they volatilize and are carried along with the steam. When the steam condenses, the filming amine will coat the walls of the pipe with a temporary wax-like film which protects the metal from both oxygen and CO_2 attack - as long as the filming amine continues to be fed. Should the filming amine be fed to a system which has already corroded, the rust will be loosened and carried to the nearest screen - often creating troublesome maintenance problems. The best results are usually obtained by feeding a solution containing 10 p.p.m. of the filming amine compound for 12 minutes (only) out of each hour. This is known as an intermittent feed.

4. Caustic soda - NaOH. Caustic soda is normally added to all boiler feedwater. One of the main advantages being that it will neutralize any acidity in the water will bring the pH up into the alkaline range - a situation which is designed to hold corrosion in the boiler to a minimum.

   Closed, recirculating water systems may be effectively protected from corrosion attack by maintaining the proper residual of surface active, soluble corrosion inhibitors. The compounds which may be used effectively as corrosion inhibitors are:

5. Chromate compounds - Chromium salts such as sodium chromate, Na_2CrO_4, or sodium dichromate, $Na_2Cr_2O_7$, form a temporary surface film which is very effective in preventing corrosion.

   To be effective, a concentration of chromates in the recirculating water should be maintained between 300 and 500 p.p.m. residual. Among the objections to using chromate is the fact that they are very toxic (poison) to man, animal, and aquatic life. This creates disposal problems for the bleed-off water when used in cooling tower water. A second objection to chromates is that they are not compatible with ethylene glycol type antifreeze (Prestone).

6. Polyphosphates - Polyphosphate compounds are commonly added to recirculating cooling water to help keep corrosion down. Polyphosphates protect the metal by forming a temporary film on the surface of the metal. A residual of

10 p.p.m. is the usual concentration which is recommended. Note that polyphosphates revert to orthophosphates when heated, so they would be ineffective as corrosion inhibitors in recirculating hot water systems.

7. Sodium nitrite-sodium borate compound. This compound is compatible with ethylene glycol type antifreeze and is quite effective as long as a residual of 1800-2400 p.p.m. is maintained.

A good point to remember, when depending on soluble corrosion inhibitors to prevent corrosion of water system equipment and components, is that while good protection is afforded when a sufficient quantity of the inhibitor is added, the corrosion rate may be accelerated in local areas (such as corners and crevices) by allowing the residual to fall too low.

SUMMARY

To the water and waste processing specialist, "scale" is a substance which results from using hard water for industrial purposes. There are several kinds of scale; however, the most common is a white, crusty deposit of $CaCO_3$. Scale deposits are very objectionable because they reduce safety factors, stop up pipes, reduce rate of heat transfer and increase amount of required maintenance. The best way to prevent scale is to remove the hardness from the water before it is used in any kind of industrial equipment. For some purposes, stabilization of the hardness compounds by the addition of polyphosphates or CO_2 will work satisfactorily.

Corrosion is the deterioration of metal by an electrochemical reaction. The most practical corrosion prevention measures for the inside surfaces of equipment through which water circulates consist of pH control (keep the pH of the water above 7) and the addition of surface active, water soluble corrosion inhibiting chemicals. The chemicals most frequently added to prevent corrosion are: chromate compounds, polyphosphates and sodium nitrite-sodium borate. These compounds prevent corrosion by forming a temporary surface film over the metal surface. Sodium sulfite is a chemical oxygen scavenger which may be added to boiler water to remove any dissolved oxygen .

QUESTIONS

1. What is the most important source of scale in industrial water systems?
2. List two reasons why scale forms in boilers.
3. What is the best way to prevent the formation of scale in boilers, when the only available water supply is hard?
4. How does "stabilization" prevent scale deposits in water distribution systems?
5. How can water be stabilized (with respect to scale deposition)?
6. List the methods commonly used to prevent corrosion in boilers.
7. List two methods commonly used to prevent corrosion in steam condensate return lines.

8. List three chemicals which may be used to prevent corrosion in recirculating water systems.

9. List two chemicals commonly used to prevent corrosion in steam condensate return lines.

10. Why would you not recommend adding a chromate corrosion inhibitor to your automobile radiator?

REFERENCES

1. Betz Handbook of Industrial Water Conditioning.

2. AFM 85-12, Operating & Maintenance of Central Heating Plants and Distribution Systems.

3. AFM 85-13, Maintenance and Operation of Water Plants and Systems.

ATC-SHEPPARD AFB TEX. 71-372

WORKBOOKS 3ABR56330-III-1-P1 Thru 8-P1

and - 3ABR5631 - III-3-P3

Department of Civil Engineering Training

17-5

Engineer Environmental Support Specialist

OPERATING PRINCIPLES OF WATER TREATMENT PLANTS

February 1972

SHEPPARD AIR FORCE BASE

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OPERATING PRINCIPLES OF WATER TREATMENT PLANTS

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This publication supersedes WBs 3ABR56330-III-1-P1, 15 May 1970; 3ABR56330-III-2-P1, 15 May 1970; 3ABR56330-III-2-P2, 19 October 1970; 3ABR56330-III-3-P1, 23 April 1970; 3ABR56330-III-3-P2, 17 February 1971; 3ABR56330-III-4-P1, 15 May 1970; 3ABR56330-III-5-P1, 10 August 1970; 3ABR56330-III-6-P1, 23 April 1970; 3ABR56330-III-7-P1, 21 May 1971; 3ABR56330-IV-5-P1, 21 September 1970.

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WB 3ABR56330-III-1-P1
22 February 1972

PRINCIPLES OF A WATER TREATMENT PLANT

OBJECTIVE

The purpose of this project is to aid you in understanding the principles, configuration, arrangement, and purpose of components in a typical water treatment plant.

COMPONENTS OF A WATER TREATMENT PLANT

PROCEDURES

Find a term in the right hand column which best fits each statement in the left hand column, then place the letter preceding the selected term in the blank preceding the statement.

1. ____ used to remove dissolved gases, iron and manganese from water
2. ____ located near the plants, used for flash mix of chemicals and water
3. ____ used to keep floc in suspension
4. ____ may be located at various points in the plant, and operate on the centrifugal force principle
5. ____ has a long retention period, 6 to 8 hours
6. ____ a retention period of 1 to 2 hours
7. ____ a storage and contact chamber
8. ____ stores water and provides pressure for emergencies
9. ____ removes suspended solids not removed by settling
10. ____ used for the injection of HTH solution

a. elevated tank
b. clearwell
c. filter
d. accelator
e. pump
f. settling tank
g. slow mixer
h. hypochlorinator
i. aerator
j. rapid mixer

COMPONENTS OF DEEP WELL

In figure 1 place the number of the components on the blank line to properly associate the two items.

_____ DISTRIBUTION SYSTEM
_____ UNDERGROUND STORAGE TANK
_____ DEEP WELL
_____ HIGH-LIFT PUMP
_____ CHLORINATOR
_____ VALVES
_____ AIR COMPRESSOR
_____ WELL PUMP
_____ PRESSURE TANK

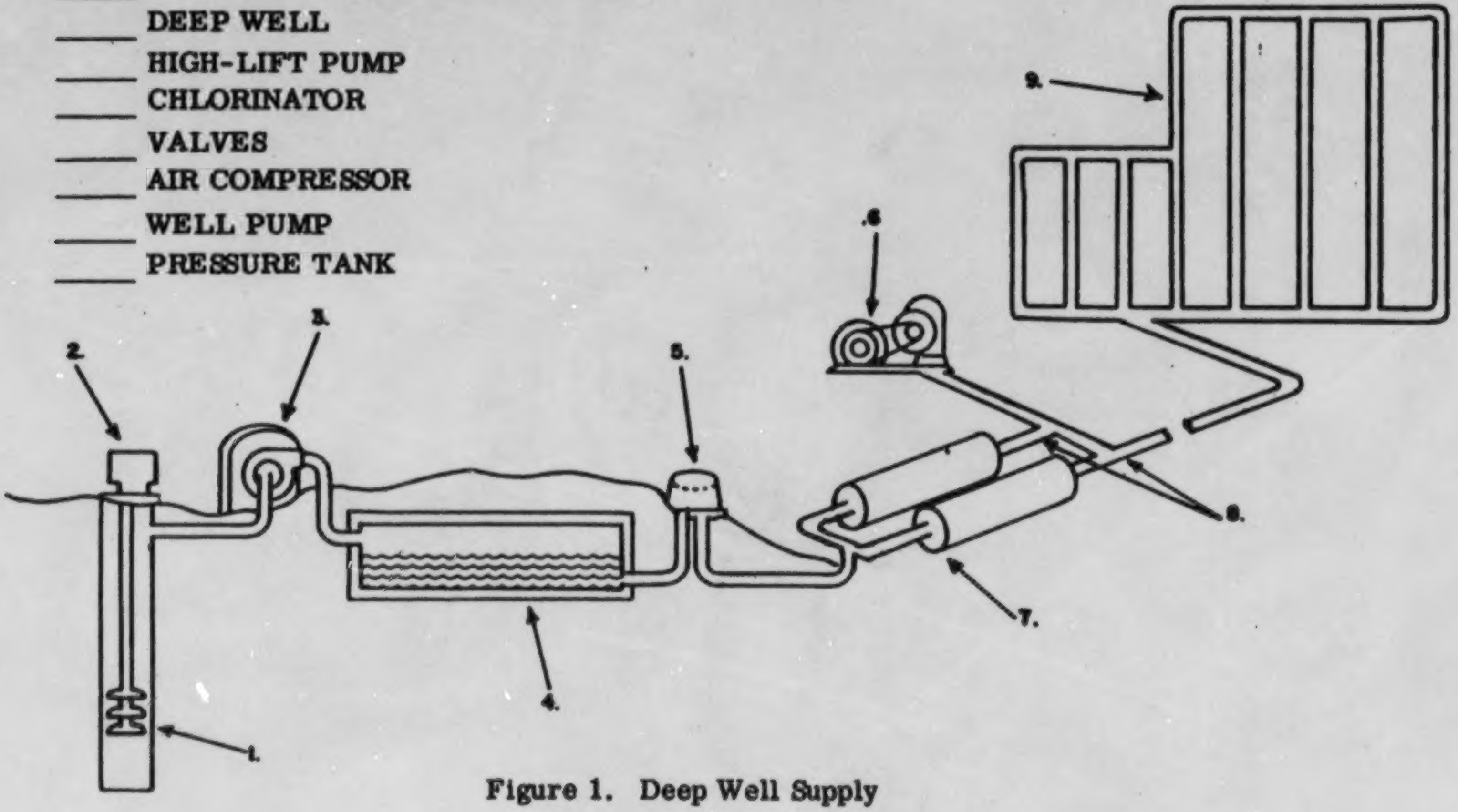


Figure 1. Deep Well Supply

COMPONENTS OF TREATED SURFACE SUPPLY

In figure 2 place the number of components on the blank line to properly associate the two items.

____ RAPID SAND FILTER
____ ELEVATED STORAGE TANK
____ IMPOUNDED RESERVOIR
____ POST CHLORINATION
____ MIXING AND FLOCCULATION
____ HIGH LIFT PUMP
____ FEEDER LINE
____ COAGULATION BASIN
____ FILTERED WATER RESERVOIR

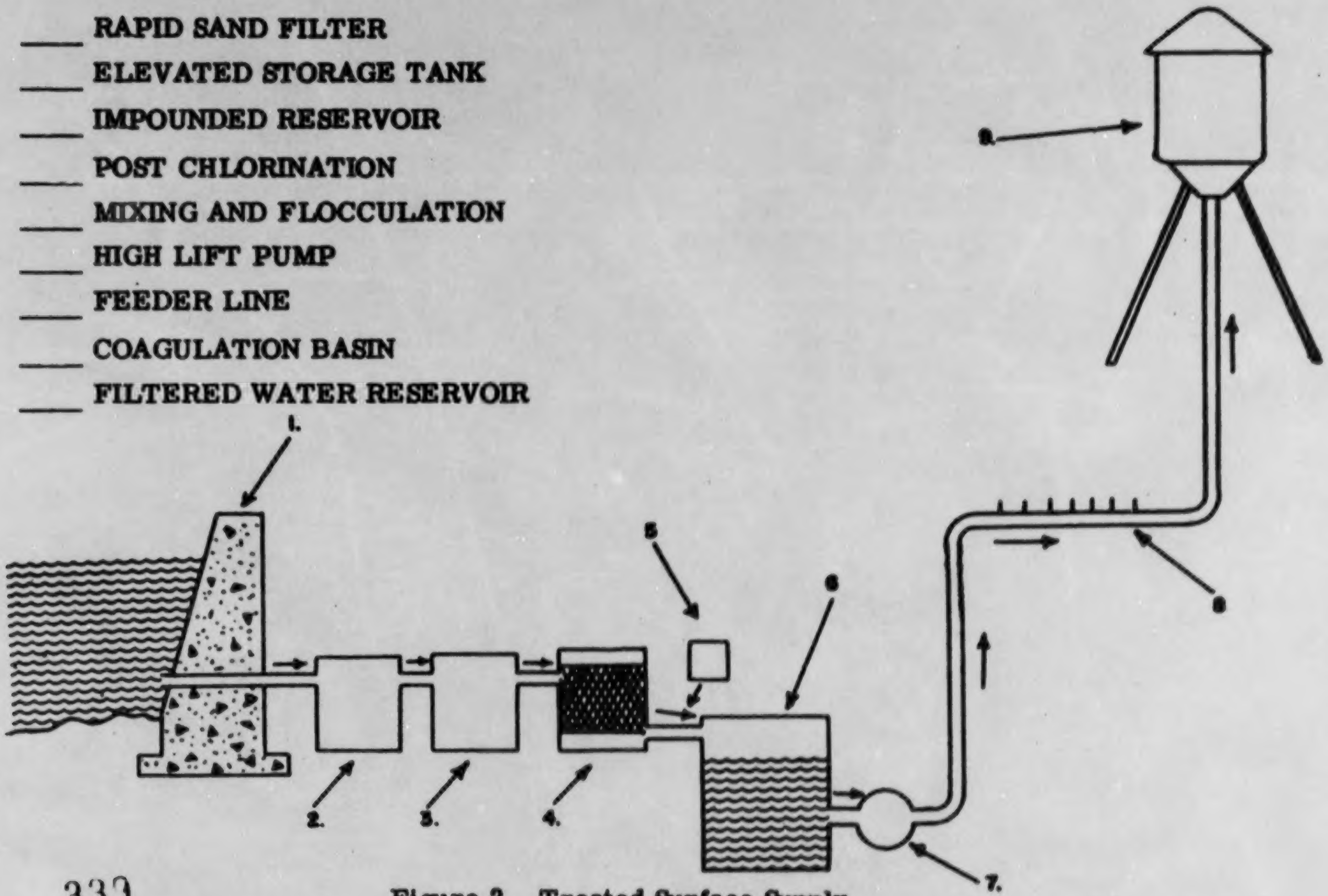


Figure 2. Treated Surface Supply

CLARIFICATION OF WATER

OBJECTIVE

The purpose of this exercise is to aid you in the clarification process of water.

PROCEDURES

Answer the following questions or define the terms used in water clarification in the spaces provided:

1. Chemical precipitation: ____

____

2. Sedimentation process: ____

____

3. Floc: ____

4. Name two minerals contributing to hardness: ____________________

____

5. What are the processes used to reduce hardness? ____________________

____

6. What is meant by stabilization? ____________________

____

7. What is scale? ____

8. How is scale controlled? ____________________________

9. What chemicals are used to control algae? ____________________

10. List a mechanical method of controlling algae: ____________________

11. Name the chemicals used to control color, taste, and odor? ____________________

12. List the test used to determine taste, color, and odor: ____________________

OPERATING A WATER TREATMENT PLANT

OBJECTIVE: The purpose of this exercise is to provide instructions for operating the Water Treatment System Trainer.

INSTRUCTIONS: Follow the procedures listed below for operating the Water Treatment Plant.

PREOPERATION

1. Close all drain valves.
2. Turn off all electrical switches.
3. Check oil in chemical feeders.
4. Mix chemical solution in chemical supply tanks.
5. Adjust chemical feeders to desired feed rate.
6. Connect the master switch panel and the settling chamber motor to a 110-volt outlet.
7. Connect the chemical feeder, rapid mixer, and floculator to the master switch panel outlets as marked.

OPERATION SEQUENCE

1. Open the globe valve on the inlet water supply and control the water flow rate at one and a half (1½) gallons per minute.
2. When the chemical mixer is half (½) full turn on the following switches:
   a. Master
   b. Chemical feeders (right and left)
   c. Rapid mixer
3. When the floculator is half (½) full turn on the motor switch.
4. When the settling chamber is full continue with the following:
   a. Open the filter inlet valve two (2) turns.
   b. Turn on the settling chamber effluent pump switch.
   c. Open the filter effluent valve one turn.
   d. Turn on the hyprochlorinator.

5. When the filter is full, turn on the clear well pump switch and open the clear well effluent valves.

BACK WASHING THE FILTER

1. Turn off the settling chamber and clear well pumps.
2. Close the filter influent and effluent valves.
3. Open the filter drain valve.
4. Turn off the hyprochlorinator.
5. Open the water lower effluent valve.

SHUTDOWN PROCEDURE

1. Turn off all electrical switches.
2. Disconnect electrical power.
3. Close the globe valve on the inlet water supply.
4. Open all drain valves.
5. Close all influent and effluent valves.

Checked by ______________________________
Instructor

IDENTIFICATION OF RAPID SAND FILTER COMPONENTS

OBJECTIVE: The objective of this exercise is to aid you in developing a better understanding of a rapid sand filter.

INSTRUCTIONS:

1. Study the drawing in figure 1.
2. Show by arrows the direction of water flow when water is flowing through the filter.
3. Show by arrows the direction of water flow when the filter is being backwashed.
4. Place the number that represents the component in the appropriate circle provided in figure 1.

1. PERFORATED LATERALS
2. WASH TROUGHS
3. CAST-IRON MANIFOLDS WITH STRAINERS ON TOP
4. GRADED GRAVEL
5. FILTER TANK
6. FILTER SAND
7. FILTER FLOOR

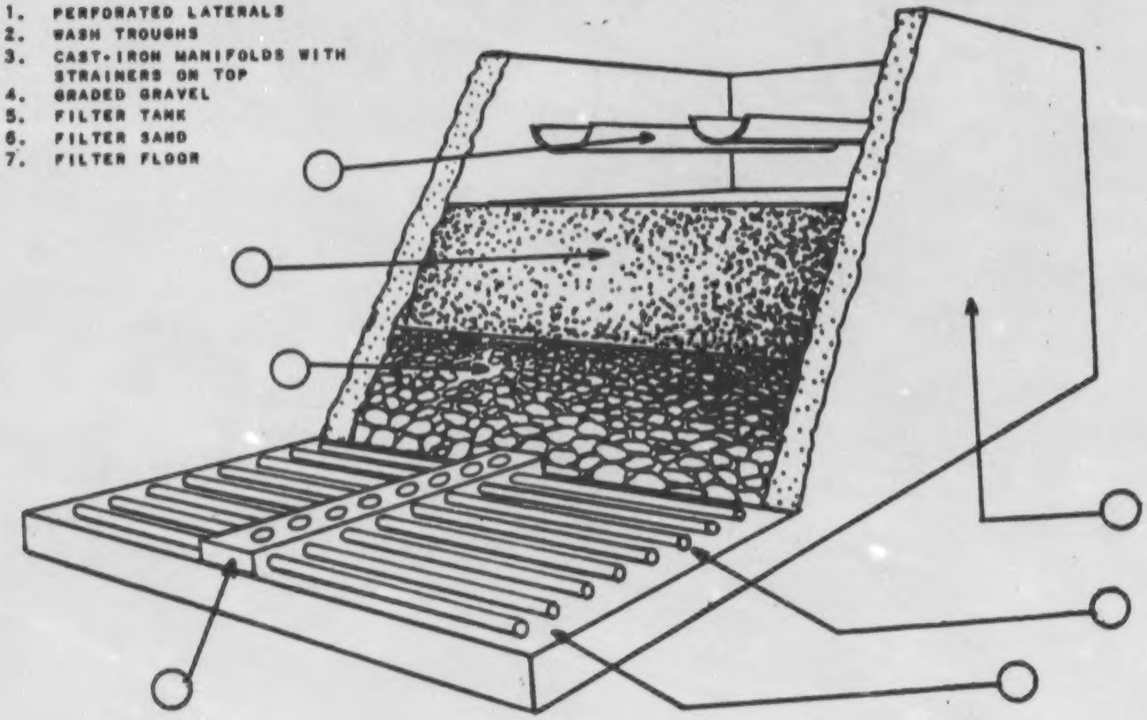


Figure 1. Rapid Sand Filter

IDENTIFICATION OF DIATOMACEOUS EARTH FILTER COMPONENTS

OBJECTIVES

The purpose of this exercise is to assist you in identifying the components of a diatomaceous earth filter.

Instructions

This workbook consists of 4 projects. The projects are listed by project number, title, and page number as follows:

● PROJECT I	- DIATOMITE FILTER ELEMENT	PAGE 2
● PROJECT II	- AIR RELEASE VALVE, GASKET AND HARDWARE	PAGE 3
● PROJECT III	- FILTER HOUSING COVER AND CLAMP ASSEMBLY	PAGE 4
● PROJECT IV	- LOWER FILTER ASSEMBLY	PAGE 5

1. Each project has a listing of items that are part of the major components. (Example: Cup__________)
2. Each project also has an exploded view of the major component with each item identified by a number.
3. For each project, you are to identify the items by placing the identification number on the blank line next to each item.

   (Example: Cup___7_____)

DIATOMITE FILTER ELEMENT
PROJECT I

Cup______________________

Retainer__________________

Rod______________________

Tube_____________________

Spacer___________________

Screw____________________

Sleeve____________________

Packing_____________________

Packing_____________________

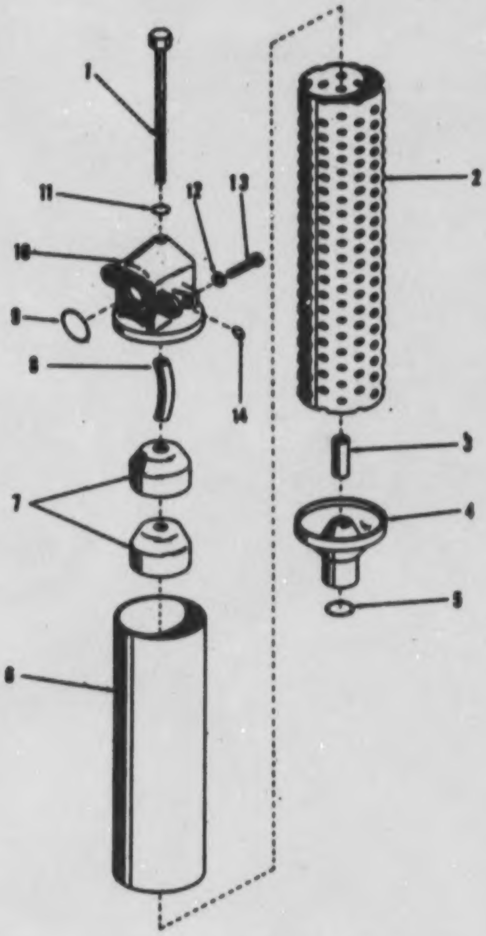
Washer_____________________

Bracket_____________________

Spacer______________________

Packing_____________________

Bracket_____________________


1
11
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9
8
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7
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2
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4
5

Figure 1. Diatomite Filter Element

AIR RELEASE VALVE, GASKET, AND HARDWARE
PROJECT II

Plate ______________________

Screw ______________________

Gasket ______________________

Nut ______________________

Plate ______________________

Screw ______________________

Valve ______________________

Washer ______________________

Screw ______________________

Plate ______________________

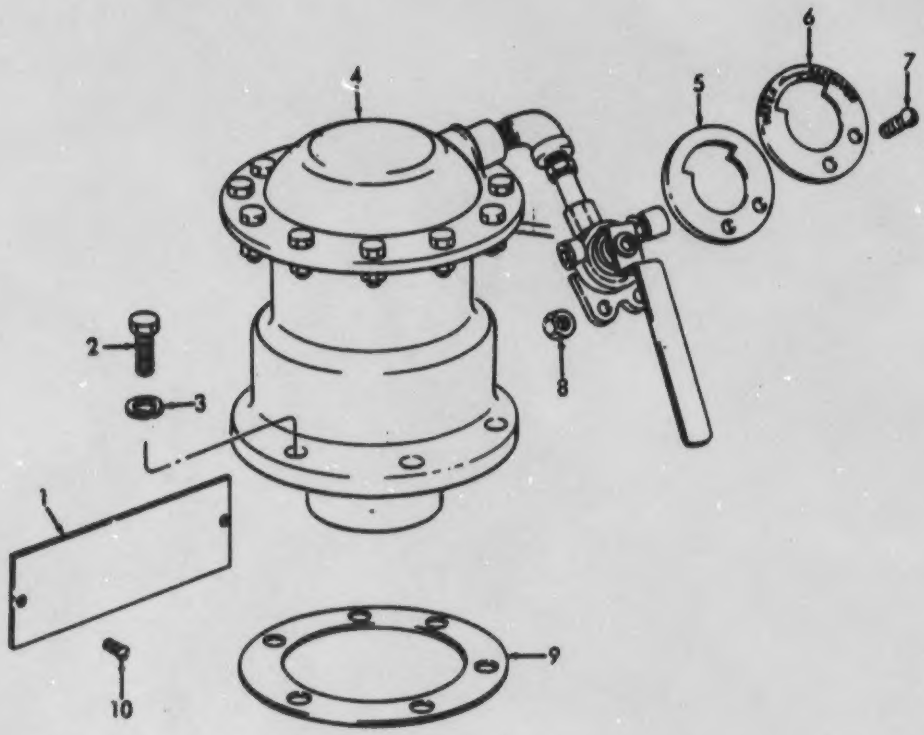


Figure 2. Air Release Valve, Gasket, and Hardware

FILTER HOUSING COVER AND CLAMP ASSEMBLY

PROJECT III

Tubing ____________________

Bushing ____________________

Cover ____________________

Screw ____________________

Elbow ____________________

Nipple ____________________

Nut ____________________

Clamp ____________________

Valve ____________________

Nut ____________________

Tube ____________________

Pipe ____________________

Clamp Assembly ____________

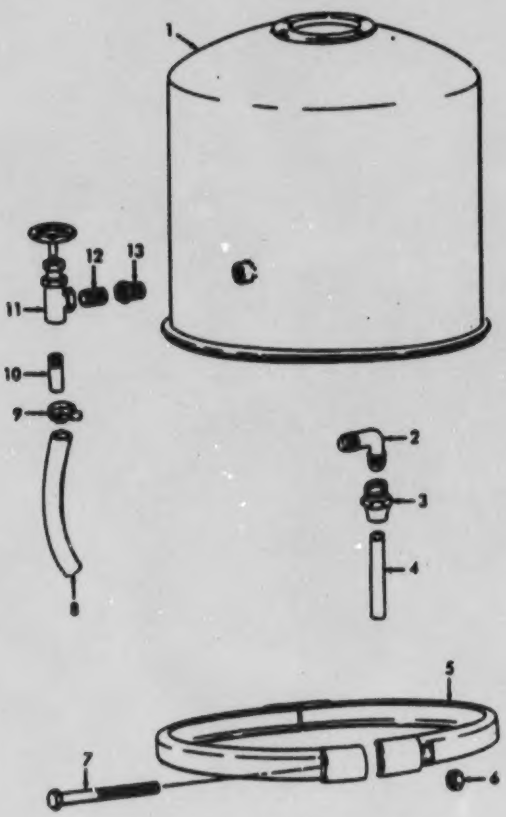


Figure 3. Filter Housing Cover and Clamp Assembly

LOWER FILTER ASSEMBLY
PROJECT IV

Nut ____________

Window ________

Washer ________

Gasket ________

Washer ________

Funnel ________

Strip ______________

Screw ______________

Gage ______________

Adapter ____________

Screw ______________

Gasket _____________

Gasket ____________

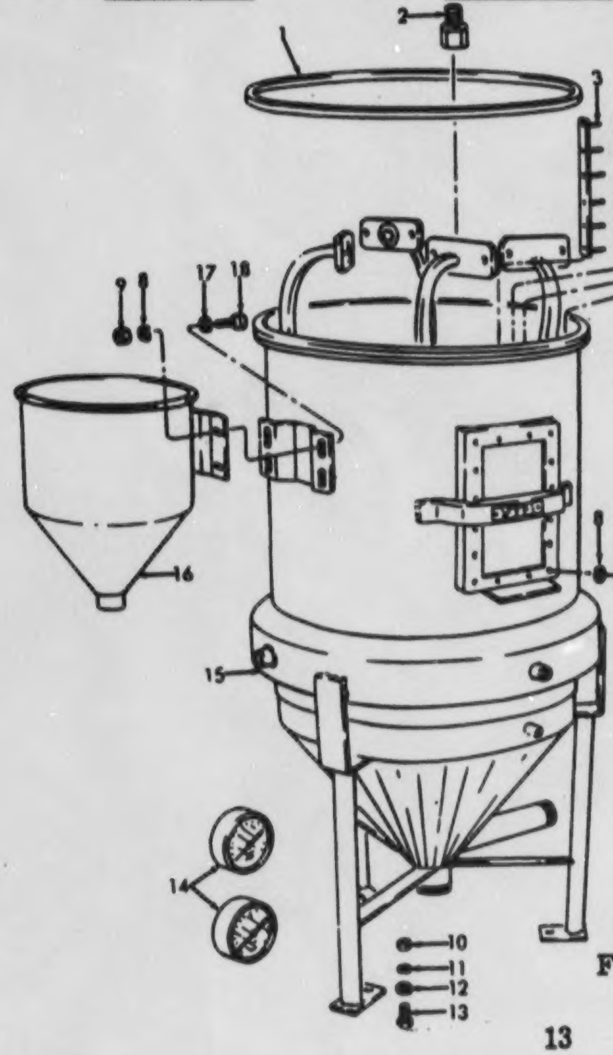
Housing ___________

Nut _______________

Strip ______________

Washer ___________

Washer ___________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18

Figure 4. Lower Filter Assembly

WATER DISINFECTION AND PURIFICATION

OBJECTIVE

The purpose of this exercise is to assist you in identifying different disinfecting agents and to operate feed equipment to add these agents in proper dosage to the water.

PROCEDURE

Complete the following exercise by placing your answer in the blank spaces provided.

1. Define disinfection: ______________________________

____

2. Define purification: ______________________________

____

3. Why does water have to be disinfected? ______________________________

____

4. List four disinfecting agents: ______________________________

5. What is the percent of free chlorine in calcium hypochlorite? _____

____

6. Define chlorine residual: ______________________________

____

7. Define chlorine demand: ______________________________

____

8. What is the reagent used when performing a chlorine residual?

____

9. Determine the dosage in ppm at a water plant using 400 lbs of chlorine per 24 hours, to treat 5 MGD:

$$\text{ppm} = \frac{\text{lbs } Cl_2 \times 1{,}000{,}000}{\text{gal. water} \times 8.3}$$

10. Name two pieces of equipment used to feed chlorine to water:

____

11. Name the points in the system where chlorine is applied? __________

____

12. Name the three types of chlorination: ____________________

____

TASTE, ODOR AND COLOR CONTROL

OBJECTIVE:

The purpose of this exercise is to familiarize you with the causes of taste, odor, and color and methods and material used to control taste, odor, and color.

INSTRUCTIONS

Complete the following exercise by answering the questions in the space provided.

1. What are the two major causes of taste, odor, and color in water?

2. List three chemicals used for the treatment of taste and odor.

3. List a mechanical treatment that would lessen taste and odor in water.

4. Define organic material.

5. Define inorganic material.

6. What effect will excessive amounts of iron and manganese have on water?

7. Define aeration.

____

____

____

8. Name at least three benefits that can be obtained through aeration of water.

a. ______________________________________

b. ______________________________________

c. ______________________________________

NOTE: For Control Test Utilization, see 563X0, Career Ladder Laboratory Manual

FLUORIDATION AND DEFLUORIDATION OF WATER

OBJECTIVE: The purpose of this workbook is to aid you in understanding the fluoridation and defluoridation processes of water treatment.

1. List the three compounds commonly used in the fluoridation of water.

2. What are the two types of chemical feeders used in fluoridation?

3. What effect does filtration have upon fluorides?

4. At what point in the water treatment process should fluorides be applied?

5. What is the recommended range of fluoride residual in treated water?

6. What is the danger of excessive fluoride residuals?

7. What are the three compounds employed in defluoridation?

8. List six applicable safety rules for working with fluorides.

9. What is the difference between gravimetric and volumetric feeders?

10. When adding H_2SiF_6, what type of solution feeders are used?

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WATER DISTRIBUTION SYSTEM

OBJECTIVE

The purpose of this exercise is to aid you in learning about a distribution system.

PROCEDURE

Answer the following questions:

1. Where does a distribution system start? ______________________

2. What is the purpose of the distribution system? ________________

____

3. State the function of the following:

   a. Mains ____

   b. Service lines ____

   c. Valves ____

   d. Storage tanks _______________________________________

4. What component in the system will allow water to flow only in one direction? ______________________________________

5. Is a well ever considered to be part of the distribution system? (explain your answer)

____

____

6. What is the purpose of an elevated water tank? _________________

____

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7. Why is it necessary to have a loop design in the system? ____________

____

8. What is the purpose of a globe valve? ______________________________

____

9. What causes water hammer? ________________________________

10. How can water hammer be prevented? ____________________________

____

INTERNAL CORROSION AND SCALE

OBJECTIVE

Upon completion of this workbook, you should have gained a better knowledge of scale and corrosion control.

INSTRUCTIONS

Place the letter preceding the selected item in the right hand column which best completes the statement in the left hand column in the appropriate blank.

1. ______ The white, crusty matter formed by the crystallation of dissolved mineral matter in water.
2. ______ A common form of pure mineral scale.
3. ______ A common scaling condition found in hot water systems.
4. ______ Undesirable effects of scale.
5. ______ An effective method for preventing scale formation.
6. ______ Any chemical treatment intended to prevent precipitation of dissolved solids.
7. ______ Most common method used in preventing scale formation in cooling tower water systems.
8. ______ Term used to describe the deterioration of metal.
9. ______ Cause of most corrosion.
10. ______ Area on a metal surface which is attacked by corrosion.
11. ______ Metal which is not corroded in a bimetallic coupling.

a. Layers of rust imbedded in accumulated mineral scale
b. Softening of all make-up water
c. Corrosion
d. Cathode
e. Dissolved oxygen
f. Filming amine
g. Sodium nitrite sodium borate compound
h. 10-20 p.p.m.
i. Scale
j. Reduces safety factors, clogs, pipes, and reduces rate of
k. Stabilization
l. An electrochemical reaction
m. Metal bond
n. Sodium sulfite
o. Sodium dichromate

12. ______ Electrons flow from anode to cathode by way of
13. ______ Accepts displaced cations from surface of the anode.
14. ______ Must be present, if corrosion is to continue.
15. ______ A chemical compound which effectively prevents corrosion in closed, recirculating water systems by scavenging the dissolved oxygen.
16. ______ A chemical compound which helps prevent corrosion in condensate return lines by neutralizing H_2CO_3.
17. ______ A chemical compound which prevents corrosion in condensate return lines by coating metal surface with a wax-like film.
18. ______ An effective corrosion inhibitor in recirculating water systems whose use is extremely limited because of its hazardous toxicity.
19. ______ An effective corrosion inhibitor in recirculating water systems that is adversely affected by hot water.
20. ______ An effective corrosion inhibitor in recirculating water systems which is compatible with ethylene glycol antifreeze.
21. ______ An insufficient amount of corrosion inhibitor in water may be worse than none at all, because
22. ______ Recommended residual of chromates in recirculating water.
23. ______ Recommended residual polyphosphates in recirculating water.
24. ______ Recommended residual of sodium nitrite-sodium borate compound in recirculating water.
25. ______ Surface active, soluble corrosion inhibitors in recirculating water systems, prevent corrosion by formation of

p. Concentrated corrosion attack in localized areas
q. 1800-2400 p. p. m.
r. $CaCO_3$
s. Bleed-off
t. An electrochemical reaction
u. Electrolyte
v. Neutralizing amine
u. Electrolyte
v. Neutralizing amine
w. Polyphosphates
x. 300-500 p. p. m.
y. Protective surface films

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Sheppard AFB, Texas

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WB 3ABR56~~330~~-III-3-P3
13 June 1972

FIELD TRIP TO MUNICIPAL WATER PLANTS

OBJECTIVE

The purpose of this exercise is to aid you in learning the operating procedures of the city water plants by observing the operation of the plant. Complete the activities listed below.

EXAMINING WATER PLANT OPERATION

Observe the operation of the plant and answer the following questions:

1. List the major components of the water treatment plants:

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

   e. ____________________

   f. ____________________

2. What type softening procedure is utilized by the water treatment plant? ____________________

3. What provisions are made for removing sludge? ____________________

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4. What is the maximum water output for each plant under normal operation? ______

____

5. What is the maximum overload water output for each plant in an emergency?

____

6. What chemicals are fed separately into the water supply? ______

____

7. Give the name and purpose of five chemicals used at either plant.

	NAME	PURPOSE
a.		
b.		
c.		
d.		
e.		

8. What type of water tests are performed in the laboratory at the water plant?

____

9. What type of filters are used at each plant? ______

10. How long does it take to backwash the filter? ______

11. How do you determine when filters are due for backwashing for each plant?

____

12. How much water is used for backwashing a filter? ______

13. What is done with the water used for the backwashing process at each plant?

____

14. Give the purpose of pre- and post-chlorination as used at the new water plant:

____

15. List any safety violations observed during the tour: ______

____

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STUDY GUIDES 3ABR56330-IV-1 Thru 5

17-5

Department of Civil Engineering Training

Engineer Environmental Support Specialist

SPECIALIZED WATER TREATMENT PROCESSES

February 1972

SHEPPARD AIR FORCE BASE

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SPECIALIZED WATER TREATMENT PROCESSES

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This publication supersedes SGs 3ABR56330-IV-1, 2ASR56350-5-I-4, 5 May 1970; 3ABR56330-IV-2, 17 July 1970; 3ABR56330-IV-3, 2 September 1970; 3ABR56330-IV-4, 9 July 1970; 3ABR56330-III-8, 8 July 1970.

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SG 3ABR56330-IV-1
22 February 1972

ION EXCHANGE

OBJECTIVE

The purpose of this study guide is to improve your knowledge of the theory and application of ion exchanges.

INTRODUCTION

Water found in streams, lakes and wells is usually hard water. Hard water causes scale to form in water lines and hard crusts to form in boilers. Hard water also kills soap suds in laundries and homes.

About 100 years ago, a farmer in England discovered that water became soft when it trickled through some of his soil. Later it was found that certain types of sand called greensand had the ability to make hard water soft. Much use was made of green sand until about 1930 when a synthetic material was invented. This new material was several times better than greensand. It could also be recharged by washing it with salty water. This new material was called resin because it was brown in color and resembled natural tree resin.

Information in this study guide will be covered in the following main topics:

- THEORY OF ION EXCHANGE
- CATION EXCHANGE PROCESS
- ANION EXCHANGE MATERIALS AND PROCESSES
- EXCHANGERS USED IN COMBINATION
- OPERATION OF DEMINERALIZERS

THEORY OF ION EXCHANGE

Ion exchange is a reversible chemical reaction between ions in water and ions in solid materials.

This definition of the ion exchange process uses some terms that are essential to a study of exchangers.

An ion is an atom or group of atoms that have gained or lost electrons. A cation is an ion with a positive charge. An anion is an ion with a negative charge. Figure 1 lists common anions and cations.

CATIONS		ANIONS	
Calcium	Ca^{++}	Bicarbonate	HCO_3^-
Magnesium	Mg^{++}	Carbonate	$CO_3^=$
Sodium	Na^+	Chloride	Cl^-
Manganese	Mn^{++}	Nitrate	NO_3^-
Iron	Fe^{++}	Sulfate	$SO_4^=$
Iron	Fe^{+++}	Silicate	$SiO_3^=$
Aluminum	Al^{+++}	Phosphate	$PO_4^=$
Hydrogen	H^+	Hydroxide	OH^-

Figure 1. Most Common Cations and Anions Removed from Water by Ion Exchangers

Ion exchange materials will not dissolve in water. They are able to release and to accept other ions in their place. The cation materials exchange positive ions for positive ions. The anion materials exchange negative ions for negative ions. The first softeners used natural sands called "zeolites." The term "zeolite" comes from two Greek words, Zein + Lithos, meaning boiling stones. In this course, the term ZEOLITE will refer to any ion exchange material.

There are four types of cation exchange materials used for water conditioning:

1. Natural sands (greensand, etc.)
2. Synthetic sands (silica-aluminum compounds)
3. Sulfonated coal
4. Cation exchange resins

    a. Sodium cycle - NaCl (salt regenerant)
    b. Hydrogen cycle - regenerated with acid - HCl or H_2SO_4

Of these materials, the plastic resins are more efficient and have higher exchange capacity so they are most widely used today. See figure 2 for data on these materials.

Exchange Process	Material Used	Appearance	Normal Capacity Grains Per Cubic Foot	Regenerant Pounds Per Cubic Foot	Strength of Regenerant	Regenerant Chemicals	Test For Exhaustion	Characteristic of Product
Sodium Cation Na + Z	Greensand (glauconite)	Grey-Green Granules	2,400 to 3,000 gr/cu ft	1.0 to 1.5 lbs/cu ft	3% to 18% Preferred 15%	Sodium Chloride Salt NA CL	1. Standard Soap 2. E.D.T.A. Total Hardness	Soft Water No Calcium Magnesium Iron
	Sulfonated Coal	Black Granules	No Data	No Data				
	Sulfonated Polystyrene	Gold-Brown Spherical Beads	24,000 to 32,000 gr/cu ft	6 to 15 lbs/cu ft				
	Na Al SiO_2 Gel	White Granules	12,000 to 15,000 gr/cu ft	4 lb to 6 lb/cu ft				
Hydrogen Cation H + Z	Sulfonated Coal	Black Granules	6,000 to 8,000 gr/cu ft	2 lbs to 4 lbs/cu ft	H_2SO_4 2% - 4% First Step Last Step 6% - 8% HC1 6% - 10%	Sulphuric Acid Hydrochloric (Muriatic) Acid	1. pH 2. F.M. Acid	Contains Acid
	Sulfonated Polystyrene	Gold-Brown Spherical Beads	12,000 to 24,000 gr/cu ft	4 lbs to 12 lbs/cu ft				

Figure 2. Cation Exchange Materials and Processes

CATION EXCHANGE PROCESSES

As shown in figure 2, there are two cation exchange processes in common use: sodium zeolite and hydrogen zeolite.

Sodium Zeolite

When hard water is passed through a bed of active sodium zeolite, the calcium and magnesium ions are taken up by the zeolite and at the same time the zeolite gives up sodium ions; this reaction is shown below. (Sodium zeolite is represented by Na_2Z.) Iron and manganese are also removed if they are not over about 10 p.p.m. in the water.

SODIUM ZEOLITE PROCESS.

Example No. 1

$CaSO_4$	+	Na_2Z	$\longrightarrow$	Na_2SO_4	+	CaZ
(solution)		(solid)		(solution)		(solid)
RAW WATER	+	SODIUM EXCHANGE RESIN		SOFT WATER	+	EXHAUSTED EXCHANGE RESIN

Example No. 2

$MgSO_4$	+	Na_2Z	$\longrightarrow$	Na_2SO_4	+	MgZ
(solution)		(solid)		(solution)		(solid)
RAW WATER	+	SODIUM ZEOLITE		SOFT WATER	+	MAGNESIUM ZEOLITE

Example No. 3

WATER FLOW --				WATER FLOW
(HCO_3)	Na Na	Produces	Ca Mg	H_2O + Na$(HCO_3$
H_2O + Ca)$(SO_4$	Na Z		Mg Z	$(SO_4$
Mg) Cl)	Na		Ca	(Cl
RAW WATER	A BEAD OF ZEOLITE		EXHAUSTED ZEOLITE BEAD	SOFTENED WATER

The process process of ion exchange is reversible. When the zeolite gives up all its sodium in exchange for calcium and magnesium, it is said to be exhausted. In order to regenerate the zeolite, the bed is backwashed, then regenerated with salty water. The sodium ions from the brine solution recombine with the zeolite, and the zeolite gives up calcium and magnesium ions which combine with chloride. The following equation shows this reaction:

SODIUM ZEOLITE REGENERATION.

Example No. 1

2NaCl	+ CaZ MgZ	$\longrightarrow$	$CaCl_2$ $MgCl_2$	+ Na_2Z
(solution)	(solid)		(solution)	(solid)
BRINE	EXHAUSTED ZEOLITE		WASTE WATER	SODIUM ZEOLITE

Example No. 2

WATER FLOW CONTAINING 15% NaCl SALT	Ca Mg Mg Z Ca	$\longrightarrow$ Produces	Na Na Na Z Na	WATER FLOW H_2O + NaCl + (Ca and Mg) Cl
BRINE SOLUTION SOLUTION	EXHAUSTED ZEOLITE		REGENERATED SODIUM ZEOLITE	WASTE SALT WATER

Calcium and magnesium chloride are soluble salts and are rinsed from the zeolite bed with clean water. Following regen regenerated, the exchange material is ready for another run to soften water.

Hydrogen Zeolite Process

Certain types of ion exchange beds can be regenerated with acid instead of salt. When this is done, hydrogen is made available rather than sodium during the softening process. The hydrogen is exchanged for calcium, magnesium, iron, and sodium ions, and the salts are converted into their corresponding acids. The reactions involved in the hydrogen exchange cycle are shown in the following equations:

HYDROGEN ZEOLITE EXCHANGE.

$CaHCO_3$ MgCl $NaSO_4$ $FeSO_4$	+	H_2Z	$\longrightarrow$	HCO_3 HCl H_2SO_4 H_2SC_4	+ Ca, Mg, Na, Fe $\rightarrow$ Z
HARD RAW WATER		HYDROGEN ZEOLITE		TREATED WATER	EXHAUSTED RESIN

Since the acids produced by the hydrogen ion exchanger are corrosive, the product water must be neutralized by a basic solution or anion exchange.

If sulphuric acid is injected into the resin stronger than 2% - 4% during the first few minutes of regeneration, the resin will be fouled with calcium sulfate ($CaSO_4$).

Operation of Ion Exchangers

The ion exchange operation cycle consists of the service-exhaustion phase and the regeneration phase.

SERVICE EXHAUSTION PHASE. During service, ion exchange capacity ranges from 10,000 to 30,000 gains per cubic foot. This is equal to about 1 to 3 pounds of impurities per cubic foot. When enough water passes through the bed to supply the rated amount of impurity, ions will start to leak through, then the bed is considered "exhausted." Actually, there is some exchange capacity remaining, but it is not usually economical to try to use it.

Three methods are used to determine when an exchanger should be regenerated. They are:

1. Time (shift, daily, biweekly)
2. Quantity (number of gallons produced)
3. Quality of water (specific conductance)

TIME. In some installations the amount of water used per day is fairly constant. It is important that service is not stopped for regeneration. The size and capacity of the ion exchange equipment are planned so that servicing is done at night, on weekends, or between shifts. Regeneration is done regardless of the state of exhaustion. Many fully automatic units are controlled by 7-day clocks that start the regeneration process after work days but not on weekends.

QUANTITY. In some installations the regeneration is done during the work day when it is needed. Probably the most dependable control device in this case is the water meter. The volume of water that the unit is expected to process is determined by the manufacturer and by operating records. The water meter is set to sound and alarm or to start regeneration when a certain number of gallons have been processed.

In the automatic system, the water meter is equipped with an electric contact head to start automatic regeneration. In the manually-operated type, the meter may be connected to an electrical contact which will ring a bell or flash a light and thus indicate the need for regeneration.

Quality of Product Controls

Monitoring of product quality is desirable because it allows an operator to produce the maximum amount of water from each regeneration and also insures good quality of water for the using agency.

Demineralizers are usually monitored with a conductance meter. The meter is set at the minimum quality standard. When ion leakage exceeds the limit, a warning sounds.

Regeneration Rinse Phase

After a bed is exhausted, it is removed from service and regenerated. Regeneration consists of three parts: backwash, regeneration-slow rinse, and fast rinse.

Backwash is provided to remove dirt, foreign solids, broken beads, and air; also to lift and reclassify the bed. Channeling and clumping are broken up and the resin is prepared for chemical treatment.

Regeneration is the chemical treatment that removes the unwanted ion through "mass-action." A high concentration of chemical reverses the normal ion exchange action, allowing the resin to be returned to the original condition. Slow rinse completes regeneration evenly throughout the bed. In some instances, slow rinse is treated as a separate step.

Fast rinse washes out the excess regenerant chemical and the ions it has removed from the bed. The rinse should continue until the normal operation condition is reached. The fast rinse flow rate is usually the same as the maximum service flow rate. See figure 3.

ANION EXCHANGE MATERIALS AND PROCESSES

There are two main types of anion exchange materials in common use in the Air Force: weakly basic resin, made of polyamine polystyrene; and strongly basic resin, made of quaternary amine polystyrene. See figure 4 for data on these materials.

Strongly Basic Anion, Hydroxyl Cycle

When the strongly base anion resins are regenerated with sodium hydroxide (NaOH), they are converted to the hydroxyl form (ROH). In this form they are used as the second stage of a demineralizer. The strong base material is the only one

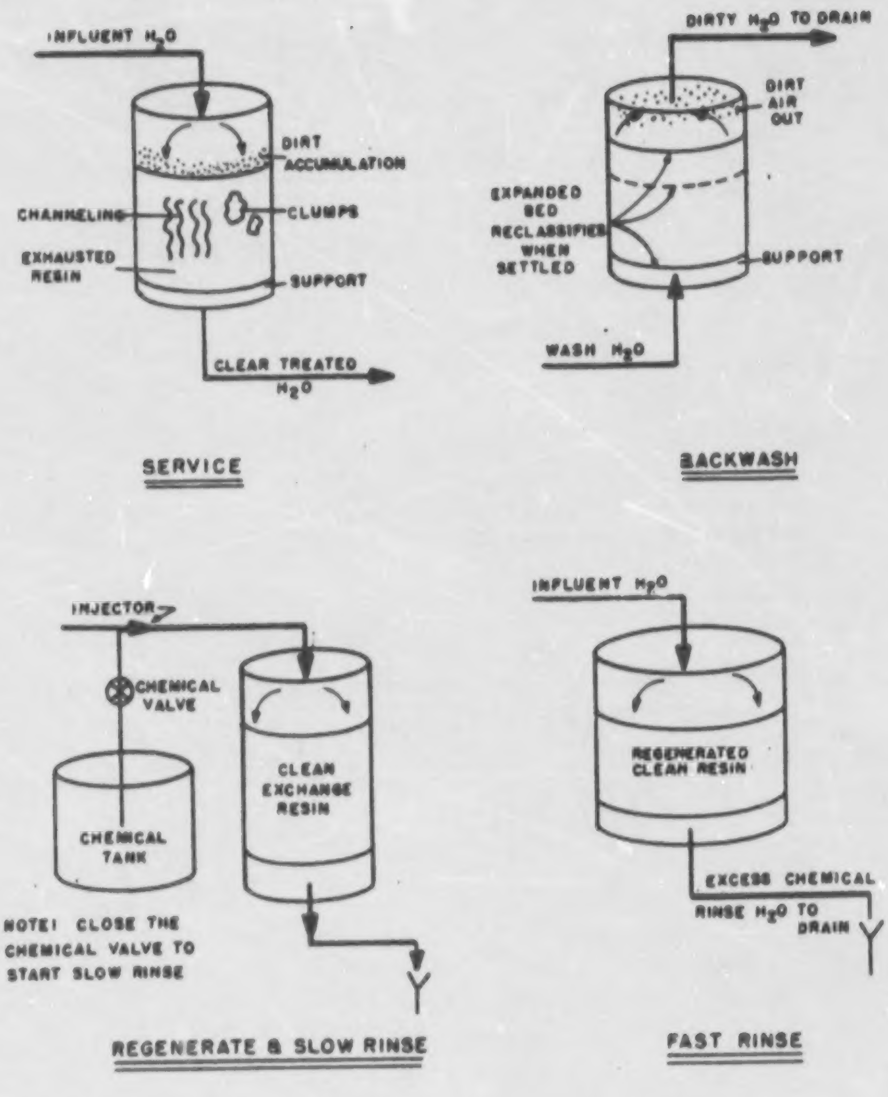
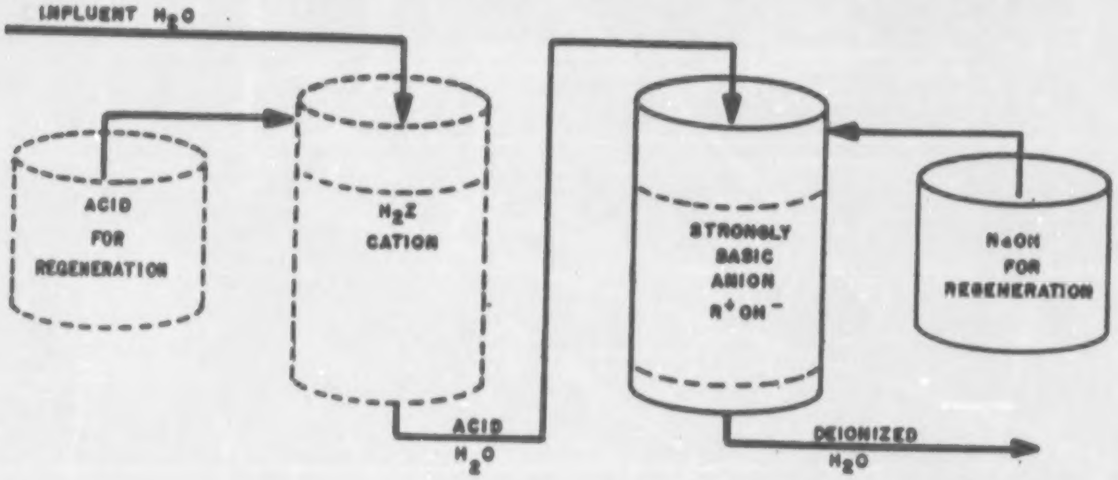

INFLUENT H2O
DIRT ACCUMULATION
CHANNELING
CLUMPS
EXHAUSTED RESIN
SUPPORT
CLEAR TREATED H2O
SERVICE
DIRTY H2O TO DRAIN
DIRT AIR OUT
EXPANDED BED RECLASSIFIES WHEN SETTLED
SUPPORT
WASH H2O
BACKWASH
INJECTOR
CHEMICAL VALVE
CHEMICAL TANK
CLEAN EXCHANGE RESIN
NOTE! CLOSE THE CHEMICAL VALVE TO START SLOW RINSE
REGENERATE & SLOW RINSE
INFLUENT H2O
REGENERATED CLEAN RESIN
EXCESS CHEMICAL RINSE H2O TO DRAIN
FAST RINSE

Figure 3. Regeneration Cycle

CLASS OF ION	MATERIAL USED	APPEARANCE	NORMAL CAPACITY GRAINS PER CUBIC FOOT	REGENERANT POUNDS PER CUBIC FOOT	STRENGTH OF REGENERANT	REGENERANT CHEMICALS	TEST FOR EXHAUSTION
WEAKLY BASIC ANION	POLYAMINE POLYSTYRENE	AMBER GRANULES	12,000 to 20,000 gr/cu ft	2 to 4 lb/cu ft	NO DATA	CAUSTIC SODA NaOH AMONIUM HYDROXIDE NH_4 OH $NaCO_3$	1. CONDUCTIVITY
STRONGLY BASIC ANION R + OH–	QUATERNARY AMINE POLYSTYRENE	YELLOWISH SPHERICAL BEADS	12,000 to 15,000 gr/cu ft	4.2 to 7 lb/cu ft	2% to 6%	CAUSTIC SODA NaOH ONLY	1. CONDUCTIVITY
STRONGLY BASIC ANION R + Cl–			5,000 to 16,000 gr/cu ft	5.0 lb NaCl Per cu ft	4% NaCl	SODIUM CHLORIDE NaCl (10% NaOH)	1. ALKALINITY

Figure 4. Anion Exchange Materials and Processes

that will remove silica and it must be regenerated with NaOH to do it. (See figure 5 for this process.) The strong base process removes all acids from hydrogen zeolite water.



Service HCl (Acid H_2O) + $R^+OH^- \longrightarrow R^+Cl^- + H_2O$ Mineral Free Product

Regeneration $R^+Cl^- + NaOH \longrightarrow R^+OH + (NaCl + NaOH)$ R^+ = Resin
Exhausted Bed Waste Water

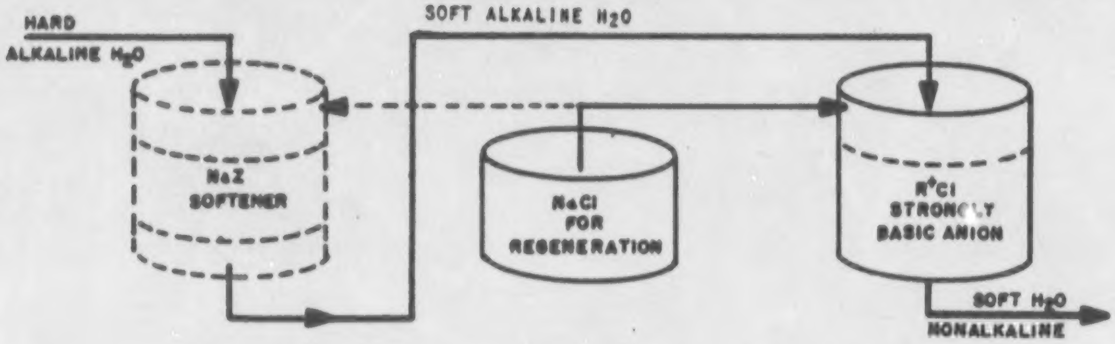
Figure 5. Strongly Basic Anion, Hydroxyl Process

Strongly Basic Anion (Chloride Cycle)

When the strongly basic anion resin is treated with sodium chloride (NaCl) salt, it is converted to the chloride form (R^+Cl^-). Softened water from a sodium zeolite unit contains all of its previous alkalinity. The RCl resin will exchange chloride ions for carbonate and bicarbonate ions. This process is primarily used for boiler feed water treatment. If 10% solution hydroxide is used with the salt for regeneration, silica will be removed by this process. See figure 6.

Weakly Basic Anion Process

The weakly basic anion exchange material (polyamine polystyrene) may be regenerated or "recharged" with soda ash ($NaCO_3$), ammonium hydroxide (NH_4OH) or sodium hydroxide (NaOH). This material is usually classed as an acid absorber rather than an exchange material. It is used as the second stage of a demineralizer process where CO_2 and SiO_2 removal are not essential. This process removes only the strong acids - HCl, H_2SO_4, H_3PO_4. See figure 7.


HARD
ALKALINE H_2O
SOFT ALKALINE H_2O
NaZ
SOFTENER
NaCl
FOR
REGENERATION
$R^{+}Cl$
STRONGLY
BASIC ANION
SOFT H_2O
NONALKALINE

Service $R^{+}Cl + NaHCO_3$ —— $R^{+}HCO_3 + NaCl$

Regeneration $R^{+}HCO_3 + NaCl$ —— $RCl + (NaHCO_3 + NaCl)$

Exhausted Bed Waste Water

Figure 6. Chloride Dealkalizer

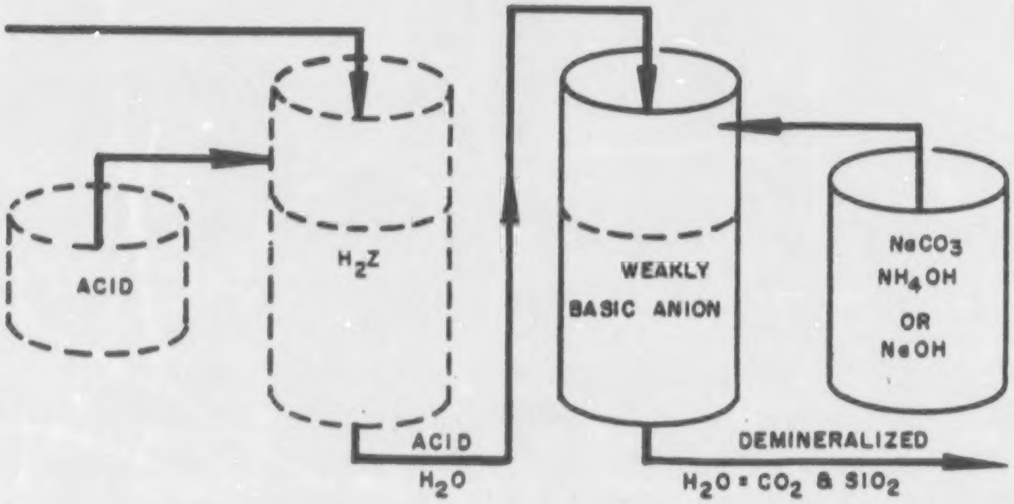
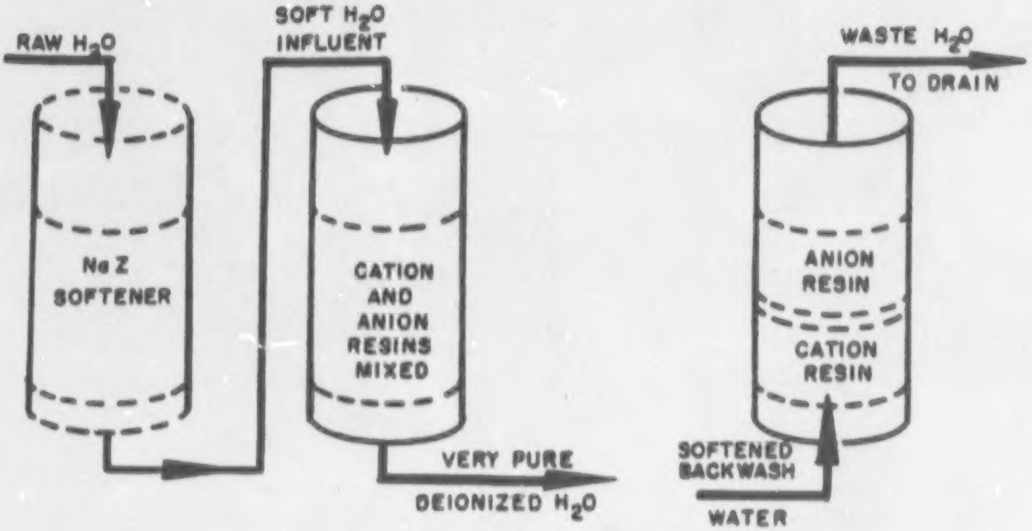

ACID
H_2Z
WEAKLY
BASIC ANION
$NaCO_3$
NH_4OH
OR
NaOH
ACID
H_2O
DEMINERALIZED
$H_2O \pm CO_2$ & SiO_2

Figure 7. Weakly Basic Anion Process

EXCHANGERS USED IN COMBINATION

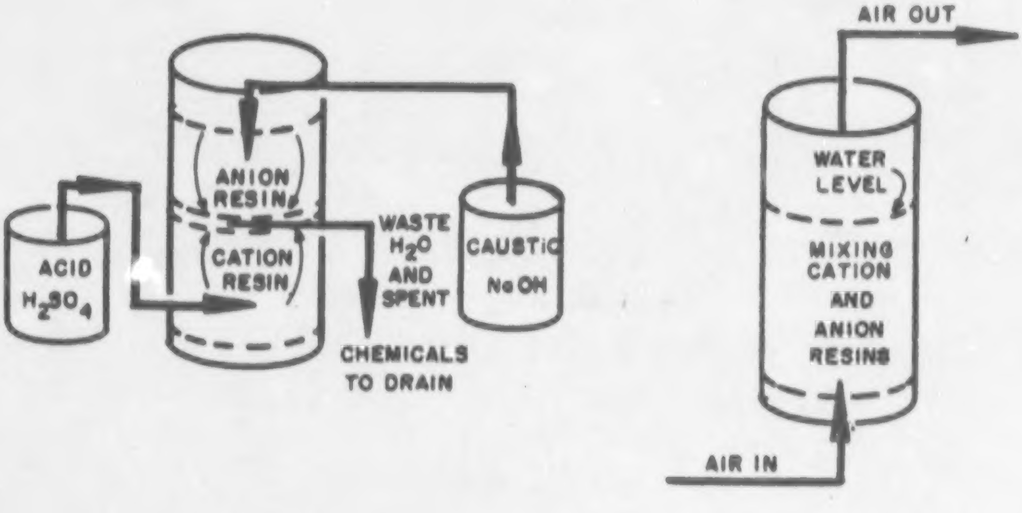
There are many combinations of ion exchange processes used to fill special requirements. The mixed-bed demineralizer is a combination of special interest.

The mixed-bed demineralizer is a combination of hydrogen cation (H_2Z) resin and strong base anion resin (ROH). These


RAW H_2O
SOFT H_2O INFLUENT
Na Z SOFTENER
CATION AND ANION RESINS MIXED
VERY PURE DEIONIZED H_2O
WASTE H_2O TO DRAIN
ANION RESIN
CATION RESIN
SOFTENED BACKWASH WATER

A. SERVICE

B. BACKWASH STEP


ANION RESIN
CATION RESIN
ACID H_2SO_4
WASTE H_2O AND SPENT CHEMICALS TO DRAIN
CAUSTIC NaOH
AIR OUT
WATER LEVEL
MIXING CATION AND ANION RESINS
AIR IN

C. REGENERATION STEP

D. AIR MIX STEP

E. FINAL RINSE STEP SAME AS STEP "A" EXCEPT THE POOR QUALITY PRODUCT GOES TO THE DRAIN

Figure 8. Mixed-Bed Demineralizer

resins are mixed in one tank and produce water of exceptionally high purity. Total dissolved solids may be reduced to less than one part per million (p.p.m.). The cation resin and anion resin are first regerated separately, then mixed. By this method, instead of having two-phase ion removal, as in other systems, there are an infinite number of exchanges as the water passes down through the column. The result of this is water containing less mineral salts than triple distilled water. See figure 8.

If raw water containing magnesium is allowed to enter an anion exchanger, the hydroxal ion will join with magnesium and form the compound magnesium hydroxide Mg $(OH)_2$. Magnesium hydroxide is in water and will form scale on the resin by the following reaction:

$$MgCl_2 + 2R^+ OH^- \longrightarrow Mg(OH)_2\downarrow + 2R^+Cl$$

Refer to figures 5, 6, 7, 8, and 9, and note that all anion exchangers have a cation exchanger ahead of them in the stream. The HZ or NaZ will remove the magnesium or other cations that may cause trouble in the anion unit.

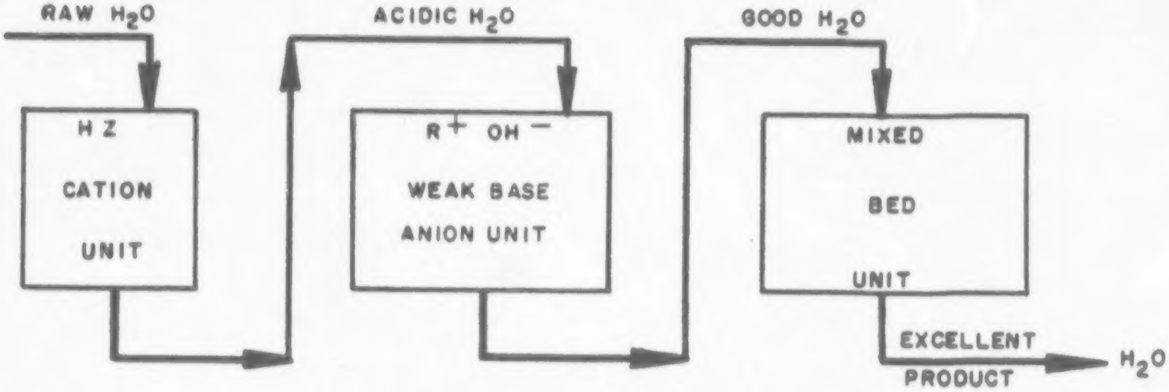


Figure 9. Combination Demineralizers

OPERATION OF DEMINERALIZERS

The controls for an ion exchange demineralized water plant are either manual, automatic, or semiautomatic. Regardless of type of controls, the operator should understand each step of the operation.

The operator should test the product for quality with the conductivity meter and check the meter on the unit by comparing the readings. It may be necessary to convert the readings from OHMS to MICROHMS or MICROHMS to OHMS. See figure 10 for conversion values.

Micro-Mhos/Cm Conductance	Ohms/Cm Resistance	p.p.m. as NaCl	p.p.m. as $NaCO_3$ Strong Base
0.5	2,000,000	0.0	0.0
1.0	1,000,000	0.3	0.2
2.0	500,000	0.6	0.4
3.0	333,000	0.9	0.6
4.0	250,000	1.5	0.8
5.0	200,000	2.0	1.0
10.0	100,000	4.5	2.0
20.0	50,000	9.5	4.0
30.0	33,000	14.2	6.0
40.0	25,000	19.0	8.0
50.0	20,000	23.6	10.0
100	10,000	47.7	20.0
200	5,000	95.0	40
300	3,330	143	60
400	2,500	200	80
500	2,000	239	100
1,000	1,000	503	200
2,000	500	1,000	400
3,000	330	1,525	600
4,000	250	2,065	
5,000	200	2,650	
7,500	133	3,970	
10,000	100	5,430	
20,000	50	11,500	

$$\text{Micro-Mhos} = \frac{1,000,000}{\text{ohms}} \qquad \text{ohms} = \frac{1,000,000}{\text{Micro-Mhos}}$$

$$\text{GPG} = \frac{\text{p.p.m.}}{17.1} \qquad \text{GPG} = \text{p.p.m.} \times 0.0584$$

Figure 10. Conductance Conversion Values at 25°C

The test for pH will also tell much about the operation condition of the unit. The range between 6.5 and 7.5 indicates normal operation. Good quality, low-mineral content water may be produced at lower or higher pH values; however, a low pH of 3 to 5 will indicate anion exchanger trouble. A high pH value will usually indicate trouble in the cation exchanger.

Regeneration of Demineralizer

When a person takes his automobile to the service station for an oil change and grease job, the service station attendant usually asks if the oil filter needs to be changed. You are probably wondering what an oil filter has to do with regeneration of a demineralizer. When the oil filter becomes covered with sludge or engine deposits, it allows some of the sludge or deposits to pass through since it has only so much holding or filtering capacity. The same principle prevails with a demineralizer. When the resin has exchanged a given number of ions for the harmful hardness impurities, it becomes exhausted and must be regenerated.

Ion exchange resin is a material which has a certain capacity of exchanging ions just as the oil filter has a certain capacity of picking up sludge. After the resin has given up ions to its capacity, it must be replenished with new ions in order to continue ion exchange process.

The term "regeneration" does not mean only the regeneration cycle, but also includes the backwash cycle as well as the rinse cycle. These cycles are all of equal importance. If one of these cycles is not completed correctly, the unit as a whole will not function properly. This may be compared with the old saying, "A chain is only as strong as its weakest link." This is also true with a demineralizer. If any part of the regeneration, backwash or rinse cycle is regenerated haphazardly, then the unit will not operate at peak efficiency. Let us consider each cycle separately and discuss its functioning.

Backwash of Cation Column

Backwash is a very important step of operation, because foreign matter has a tendency to act as a plug which restricts the flow of water. It also reduces the exchange capacity of the resin as it coats the resin beads. Figure 11 shows foreign matter being coated onto the resin beads. Figure 12 illustrates the backwash cycle removing the deposits from the beads. From observing figures 11 and 12, it can be seen readily why backwashing is an important step in the operation of demineralizers.

It is a good practice to place a beaker or large mouth container beneath the backwash outlet to observe the waste water for any resin that is being backwashed from the column and for determining when backwash water becomes free of turbidity.

Chemical Injection for Cation Column

When the regeneration cycle is initiated, the cations which have been removed by the resin are exchanged for new hydrogen cations from sulfuric acid (H_2SO_4). It is important to remember that each column, the cation and the anion, are regenerated and rinsed separately.

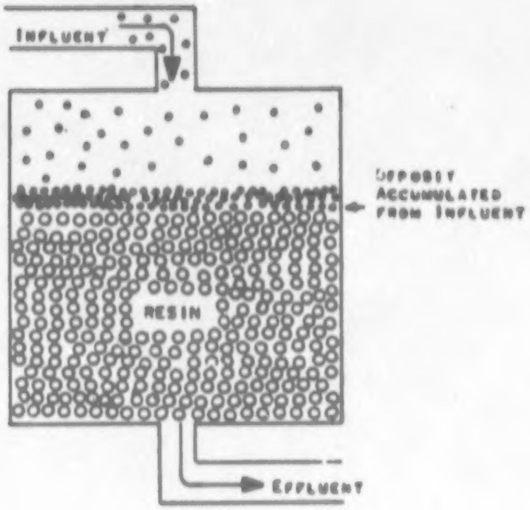


Figure 11. Deposits Forming a Coating on Resin Surface

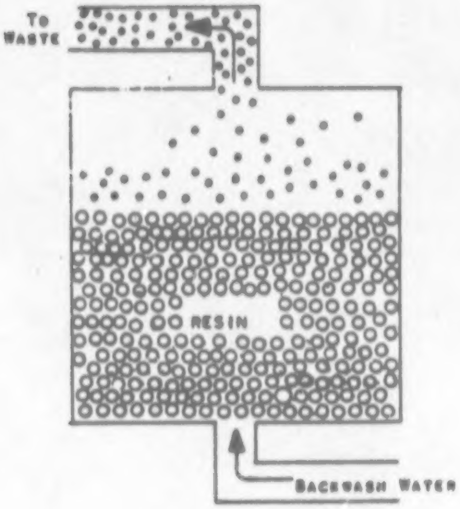


Figure 12. Deposits Being Removed from Resin Surface by Backwashing

A word of caution: Baume 66° (H_2SO_4) and flake caustic soda (anion regenerant) are both dangerous materials to handle and work with. A person could receive severe burns from either of these chemicals if the proper precautions are not observed. Use all safety equipment at your disposal. This equipment should consist of acid-proof apron, gloves, goggles, and footwear.

After the backwash cycle has been completed, the next cycle is regeneration. To regenerate the cation bed, the acid is prepared and used according to the following procedure.

1. Fill acid tank partially with water.
2. Measure the exact amount of acid required.
3. Slowly pour acid into the water while stirring constantly.
4. Add make-up water to the recommended tank level.
5. By following the manufacturer's instructions, open or close the correct valves and start the water flow at the prescribed rate for the regeneration step.
6. Continue this phase of regeneration until the correct amount of acid has been pulled from the tank.
7. After regeneration has been completed, rinse the acid tank to prevent an unsafe condition.

Figure 13 illustrates the regeneration cycle of a cation unit.

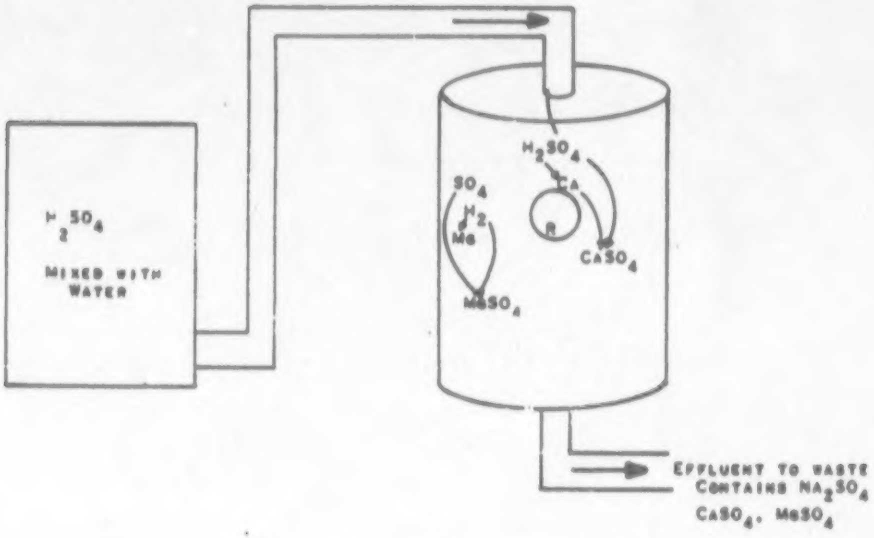


Figure 13. Regeneration with H_2SO_4

The last step in the regeneration cycle of the cation column is the slow and fast rinse cycles. The slow rinse completes regeneration and fast rinse removes excess acid or base left by the regenerating material. By all means, follow the manufacturer's instructions for operation of demineralizers as it is impossible for this student text to contain all information pertaining to each type demineralizer being throughout the Air Force.

Regeneration Cycle for Anion Column

Regeneration cycle of the anion column is similar to the regeneration cycle of the cation column.

Anion Backwash

The water flows upward through the resin to remove dirt and air and to loosen or reclassify the bed. The flow rate must be slower than for cation resin because the anion resin is lighter and will wash out easier.

Chemical Injection (NaOH)

The procedure for mixing flake caustic is the same as for sulfuric acid.

CAUTION: The dust of flake caustic is very active and will burn your eyes and respiratory system.

1. Partially fill caustic tank with water.
2. Measure exact amount of liquid of flake caustic soda.
3. Slowly add NaOH to the water in the tank and stir until dissolved.
4. Fill caustic tank to recommended level.
5. Inject caustic solution at proper flow rates. NOTE: DO NOT stir after injection has started.
6. Rinse caustic tank after regeneration is complete.

Slow Rinse

After all the caustic has flowed into the resin, the same flow rate is continued to complete the regeneration of all parts of the bed.

Fast Rinse

Fast rinse removes the excess caustic. The flow rate is set near the maximum service flow rate.

The conductivity meter is set at the lowest quality water that is acceptable. When the meter lights change, the rinse is complete; and the water is ready for service.

SUMMARY

Ions are electrically charged atoms or groups of atoms. Ion exchange is a reversible chemical reaction between ions in solution and ions in solid materials.

The process of ion exchange has been known for many years but the commercial use of the process is very recent. New uses of the materials and new materials are being developed all the time.

The common ion exchange materials are natural aluminum-silica sand, man-made aluminum-silica gel, sulfonated coal, and the plastic resins. The resins are now in most common use.

Sulfonated polystyrene will exchange cations and may be used on the sodium cycle as NaZ or on the hydrogen cycle as H_2Z. As NaZ, it will soften water by removing calcium and magnesium. As H_2Z, it will remove all cations and replace them with the H^+ ion. The hydrogen ion changes all salts to acid.

Ion exchange materials are reusable because they may be regenerated. Regeneration removes the impurities and restores the resin to its former operating state. Regeneration is achieved by "mass action" of an excess of regenerant chemical.

The regeneration phase consists of backwash to clean the bed, chemical injection to restore the bed, slow rinse to complete regeneration, and fast rinse to wash out the extra chemical.

There are two types of anion exchange material, weakly basic and strongly basic. The weak base material removes the strong acids only. The strong base material will operate on the hydroxal cycle or on the chloride cycle. The OH^- cycle is used to dealkalize boiler water.

A cation exchanger is always installed ahead of an anion exchanger to prevent scale fouling of the resin.

When mixing strong chemicals. ALWAYS ADD THE CHEMICAL TO THE WATER. The steps of regeneration are:

Cation exchanger	Anion exchanger
1. Backwash	1. Backwash
2. Acid injector	2. Caustic injection
3. Rinse	3. Final rinse

The quality of demineralized water is checked with a conductivity meter that may be calibrated in Micro-Mhos or ohms.

QUESTIONS

1. How is a cation formed?
2. How is an anion formed?
3. What is ion exchange (brief)?
4. What is an ion exchange material?
5. Name four ion exchanger materials.
6. Name four ion exchange processes (uses of resins)?
7. What is the purpose of backwash?
8. What is the purpose of chemical regeneration?

9. Convert 20 Micro-Mhos to ohms.

10. Where are specific instructions found for the operation of an ion exchanger?

11. What chemicals are used for regeneraion of a cation unit?

12. What chemicals are used for regeneration of a weak base exchanger?

13. What chemicals are used for regeneration of a strong base exchanger?

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3. Boiler Feed and Boiler Water Softening - Blanning and Rich

ELECTRODIALYSIS DEMINERALIZATION

OBJECTIVE

The purpose of this study guide is to teach you the electrodialysis demineralization process of water treatment.

INTRODUCTION

Some industrial and chemical processes require more complete demineralization than is normally given a domestic supply. Conversion of sea and brackish water to a usable supply is also a special process of demineralization. These more exacting requirements are met by distillation and ion exchange processes. A more recent development is the electrical membrane process, called "electrodialysis".

This study guide is designed to acquaint you with the electrodialysis demineralization process. This information will be given under the following topics:

- PRINCIPLE OF ION ATTRACTION BY ELECTRICITY
- BASIC OPERATION OF PERMEABLE MEMBRANES
- PRINCIPLE OF MEMBRANE DEIONIZATION
- FLUID FLOW CHARACTERISTICS AND CONTROL
- MEMBRANE STACK ASSEMBLY

This study guide will not contain all the information that you need to know; therefore, additional study is recommended.

PRINCIPLE OF ION ATTRACTION BY ELECTRICITY

If a direct current potential is applied across a solution of salt and water by means of two electrodes in the solution, the cations will move toward the negative electrode which is known as the cathode, and the anions will move toward the positive electrode which is known as the anode. Let us consider a solution of sodium chloride in water. The cations ($Na+$) and anions ($Cl-$) are moving about at random as illustrated in Figure 1.

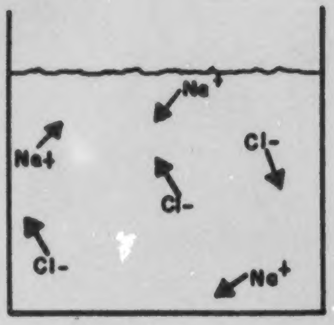


Figure 1. Sodium and Chloride Ions in Solution

In Figure 2, a direct current potential has been introduced in the solution and the chloride anions move toward the positive electrode while the sodium cations move toward the negative electrode. Typical natural waters contain varying amounts of sodium, calcium, and magnesium as cations (positively charged) and chloride, sulfate, bicarbonate, or nitrate as anions (negatively charged). When these saline waters are exposed to a direct current, all the cations will move in one direction, toward the cathode, and all the anions will move in the opposite direction, toward the anode. Thus by the use of a direct current potential, ion movement can be used to deionize water if suitable means are available to control the ion movement and prevent the removed ions from re-entering the purified water.

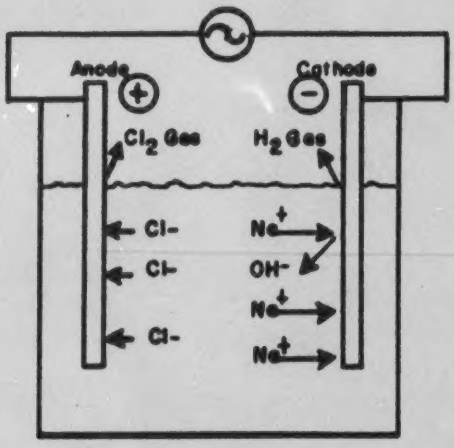


Figure 2. Effect of Current in Sodium Chloride Solution

BASIC OPERATION OF PERMEABLE MEMBRANES

Advantage could be taken of this movement of ions if proper barriers were available to isolate the purified zone to prevent remixing with the ions. The permeable membrane is one such barrier. This membrane is a thin sheet of ion exchange material, commonly 4 to 40 thousandths of an inch thick. In this sheet of ion exchange material are millions of very fine capillary pores which honeycomb the structure. Although these pores contain water, their minute size, the largest being one millionth of a centimeter in size, prevents a permeating flow of water. Ions, though, are capable of passing through these pores. (The membrane is permeable to ions but impermeable to water at normal pressures.)

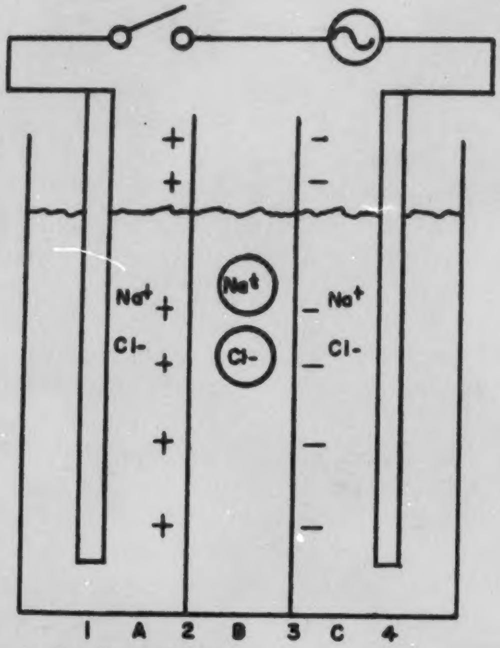
Each permeable membrane sheet contains either a positive or negative charge, depending on the type of ion exchange material used.

The pores of the particular membrane sheet are either positively or negatively charged, hence the term anion or cation membrane. The cation membrane, being negatively charged, will attract cations which are positively charged and will repel anions that are negatively charged. This principle is due to a law of physics which states that like charges repel and unlike charges attract. In a like manner, the anion membrane will attract only anions and will repel cations. However, these ions that are attracted by their appropriately charged membrane are not held by that membrane but pass through to the next compartment. This is because the electrodes that have been immersed in the solution provide the ions with enough momentum to pass through the membrane without being caught.

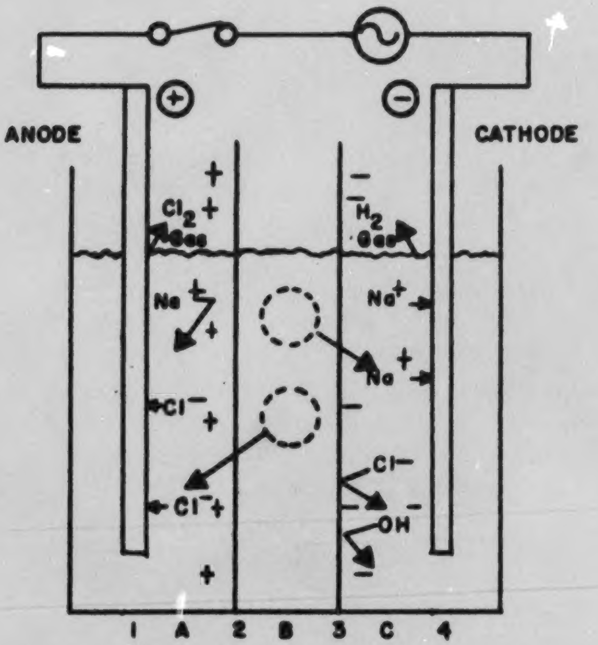
Even if the ion were to be caught on the ion exchange material, the force of the electrode would be sufficient to pull the ion loose by brute force. In the three-cell unit shown in Figure 3B, it can be seen how anions and cations will collect in cells A and C and deionized water will be retained in cell B.

At the bottom of the cell shown in Figure 3, the number "1" denotes the anode (positive electrode), "2" is the anion membrane (positive charge), "3" is the cation membrane (negative charge), and "4" is the cathode (negative electrode). In Figure 3A, we show no electrical flow; the switch is open. In this situation, the ions will move at random in their respective compartments. However, in Figure 3B, we have closed the switch and introduced a current to the system. The anode electrode is positively charged and the cathode electrode is negatively charged. The cations (Na+) move toward the cathode and the anions (Cl-) move toward the anode. The following action occurs in each compartment.

1. Na+ from compartment A cannot pass through anion membrane 2 into compartment B, because like charges repel each other.


Na+
Cl-
Na+
Cl-
Na+
Cl-
1
A
2
B
3
C
4

A- No Electric Flow


ANODE
CATHODE
Cl2 Gas
H2 Gas
Na+
Na+
Na+
Cl−
Cl−
Cl−
OH
1
A
2
B
3
C
4

B - Electric Flow

Figure 3. Basic Operation of Permeable Membrane

2. Na+ from compartment B passes through cation membrane 3 into compartment C and is repelled by anion membrane 2.

3. Cl- from compartment B passes through anion membrane 2 into compartment A and is repelled by cation membrane 3.

4. H+ from ionized water in compartment C reacts at the cathode to give off hydrogen gas and the Na+ ion reacts with the hydroxyl ion left to form NaOH.

5. Cl- from compartment C cannot pass through cation membrane 3 into compartment B and is thus retained in compartment C.

The above actions, using Na+ and Cl-, to illustrate the movement of the ions is not restricted to Na+ and Cl- but includes all positive ions (cations) such as sodium, potassium, calcium or magnesium, and all negative ions (anions) such as chloride, sulfate, or bicarbonate. Now it can be seen how the overall effect has been a demineralization of the central compartment.

PRINCIPLE OF MEMBRANE DEIONIZATION

As stated before, the electric membrane process removes ionized salts and minerals from water by the migration of ions through ion-transfer membranes in a direct current electrical field. We have also observed how these ion-transfer membranes are selective in the passage of ions and by being selective, are able to retain other ions that cannot pass through the membrane. However, to be of any use, we must enlarge the capacity of the unit. To do this, we merely add alternating cation and anion membranes between the electrodes, forming compartments for the ion containing water between each pair of membranes. The movement of the ions due to direct current is affected as shown in Figure 4.

The negative electrode (cathode) is at the bottom of Figure 4. Due to its negative charge, all cations (positive charges) will be attracted to it and will try to move down. However, only those cations whose lower boundary is a cation membrane (compartment 2, 3, 5, 7, 9, and 10) can move down. These cations can move only one compartment after passing through the cation membrane because they next encounter an anion membrane. Cations cannot pass through an anion membrane and are repelled away from the anode. The cations are not stuck to the membrane but are trapped in the compartment. Water forced to flow through the concentrate streams will wash the cations out of the unit.

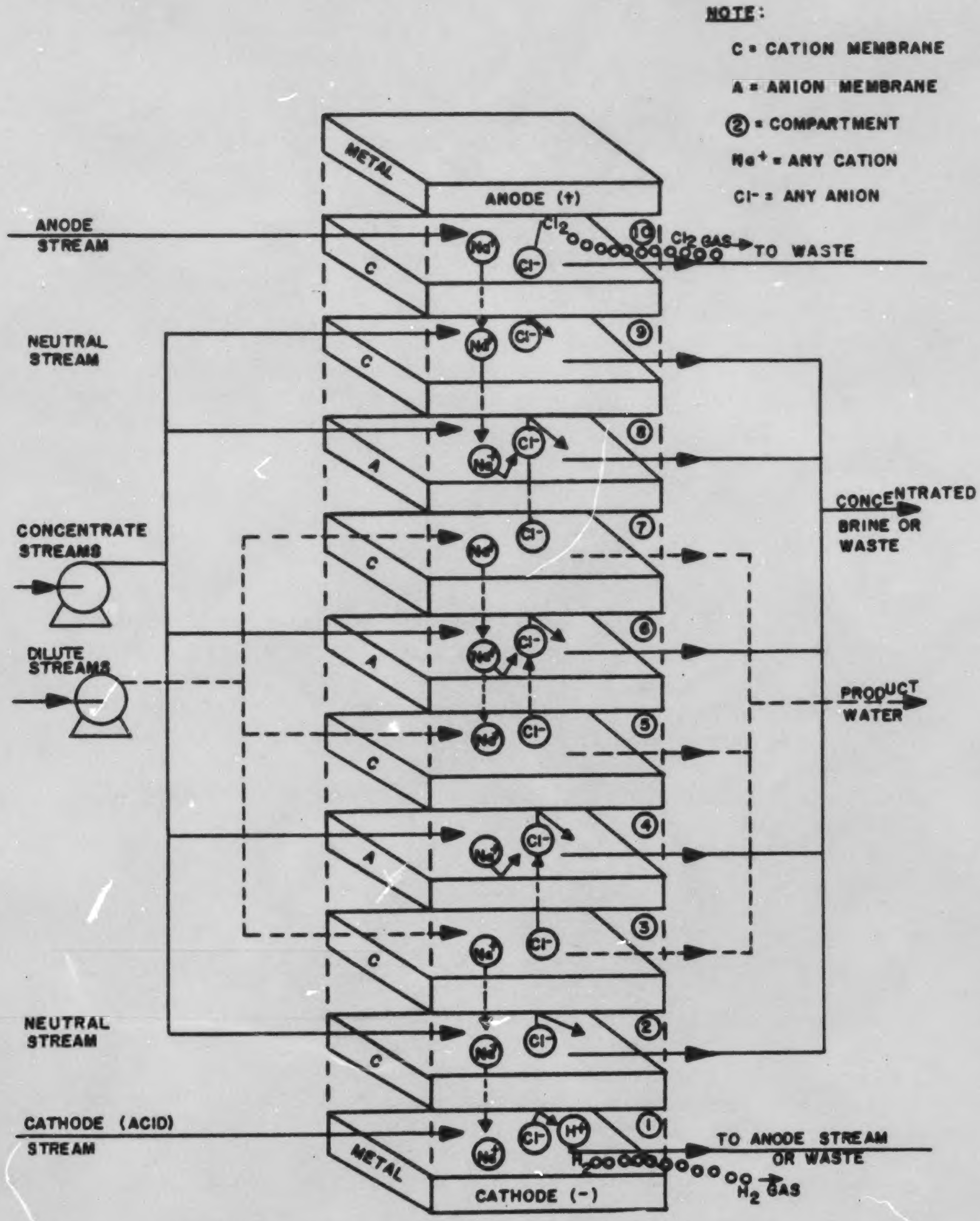

NOTE:
C = CATION MEMBRANE
A = ANION MEMBRANE
② = COMPARTMENT
Na⁺ = ANY CATION
Cl⁻ = ANY ANION
METAL
ANODE (+)
ANODE STREAM
Na⁺
Cl⁻
Cl₂
⑩
Cl₂ GAS
TO WASTE
C
NEUTRAL STREAM
⑨
C
⑧
A
CONCENTRATED BRINE OR WASTE
CONCENTRATE STREAMS
⑦
C
DILUTE STREAMS
⑥
A
PRODUCT WATER
⑤
C
④
A
③
C
NEUTRAL STREAM
②
C
CATHODE (ACID) STREAM
①
H⁺
H₂
TO ANODE STREAM OR WASTE
H₂ GAS
METAL
CATHODE (-)

Figure 4. Water and Ion Flow in an Electric Membrane Stack

In like manner, the positive electrode will attract all of the anions upward. All anions with anion membranes above (compartment 3, 5, and 7) will be able to move up one compartment. After passing through the anion membrane, the next membrane which is a cation membrane will prohibit any further travel of the anions. Those anions which initially had a cation membrane above (compartments 2, 4, 6, 8, and 9) are prevented from moving to another compartment. These anions have no desire to move downward due to the repelling force of the cathode. The concentrate streams will also remove these anions at the same time it is removing the cations.

At the bottom of the unit, compartment 1 (containing the cathode) will retain anions and gain cations. In this manner, as long as brine is flowing through the unit, compartment 1 will continually gain cations. Eventually the concentration of cations will become so heavy that they will tend to become depolarized or lose most of their efficiency due to concentration of positive ions beginning to repel other positive ions. Therefore, periodically compartment 1 must be flushed to remove the cation concentration and introduce a dilute brine solution. This flushing may also prevent the precipitation of salts which would have a tendency to coat the cathode itself and partially plug the cation membrane to the right. At the same time that this action is taking place, the cathode is also attracting positively charged hydrogen ions to it. These hydrogen ions obtain an electron from the cathode and when two of these neutralized hydrogen atoms contact each other, they form a molecule of hydrogen gas, float to the top of the water and are vented to the atmosphere. Safety precautions should be taken here to prevent fire hazards due to the burning properties of hydrogen gas.

Hydrogen when vented leaves behind it an hydroxide (OH^-) ion. It is this ion which may control the rate or the frequency at which we must flush out the compartment. As magnesium and/or iron are positively charged ions, they will be attracted to the negatively charged hydroxide (OH^-) ion. Once contact is made between these positively and negatively charged ions, due to the low solubility of the resulting compound, a precipitate is formed.

$$Mg^{++} + 2(OH)^- \longrightarrow Mg(OH)_2 \downarrow$$

$$Fe^{+++} + 3(OH)^- \longrightarrow Fe(OH)_3 \downarrow$$

As no precipitate can be tolerated in this unit, the concentrations in compartment 1 must be controlled. This is for the most part automatically controlled, in that acid is usually fed to the influent water to prevent polarization of the permeable membranes, and the slightly acid solution will prevent the precipitate from forming.

In compartment 10 containing the anode, we have other concentrations of ions building up. Here again, the concentrated solution of ions must be flushed out periodically for efficient operation. In this compartment, the negative ions such as chloride are attracted to the anode, in addition to other anions. However, as in the case of hydrogen at the cathode, the chlorine atoms combine to form chlorine gas and must be vented from the unit.

In Figure 4, we can observe the net result of these ion transfers. In compartments 3, 5, and 7 the anions all move upward and the cations all move downward. This results in a purified water in these compartments, so they are all connected to the same outlet as represented by the dotted line at the right of the unit. The compartments 2, 4, 6, and 8 are gaining ions (impurities) all the time. These compartments give off a water containing many impurities (ions) and this water is sent to waste. In most cases, this water is circulated back through the compartments to pick up additional ions prior to being disposed of. Once the concentration approaches the point where precipitation may begin, the water is then flushed out to waste and replaced by a less concentrated brine. This conserves the amount of water used to remove the ion impurities.

FLUID FLOW CHARACTERISTICS AND CONTROL

Various pumps, control valves, instruments, and electrical equipment are required to operate a membrane stack. Figure 5 is a diagram of a single stack, two-stage plant. Water to be demineralized enters from the left and is cleaned in filter (F). The pressure is controlled by the pressure reducing valve (PRV) before the stream divides into product and concentrate streams. The concentrate stream make-up water passes through rotometer (R_1) which shows the bleed-off rate. (Bleed-off = Make-up.) Pump-1 circulates the concentrate stream through the stack and also through all other stacks in the plant.

The product or dilute stream is pumped through the first stack by Pump-1. Rotometer R_2 shows the rate the plant is processing water. The membranes may be damaged if the dilute stream and waste stream pressures in the stack are not kept balanced. Each stack will have an instrument panel with a mercury manometer and two or three pressure gages. During normal operation the instrument readings should be similar to these:

Dilute Pressure IN	40 PSI
Concentrate Pressure IN	39 PSI
Dilute Pressure OUT	2 PSI
Mercury Differential	2 inches
Three-Way Valves set to	IN

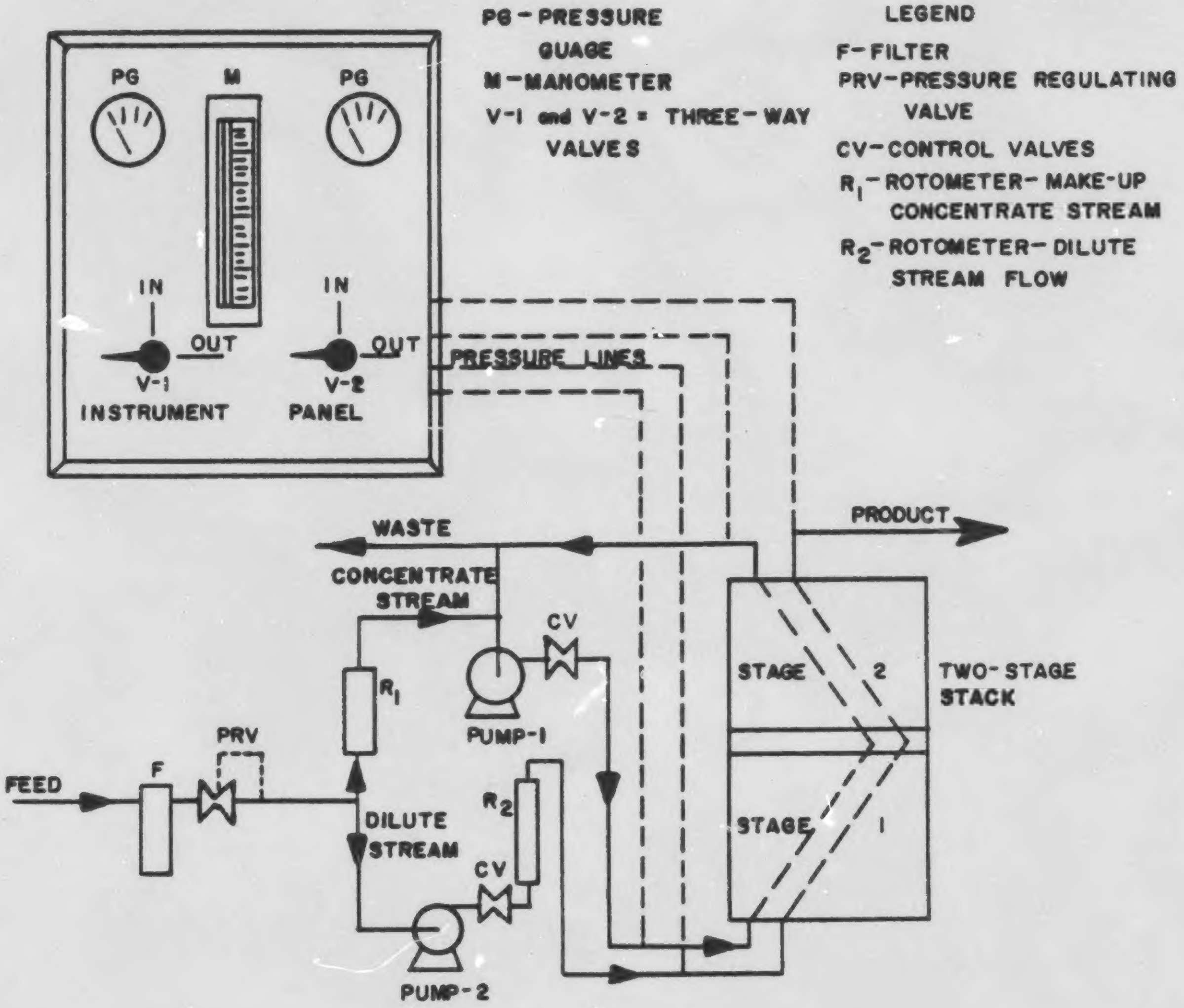

PG - PRESSURE GUAGE
M - MANOMETER
V-1 and V-2 = THREE-WAY VALVES
LEGEND
F - FILTER
PRV - PRESSURE REGULATING VALVE
CV - CONTROL VALVES
R_1 - ROTOMETER - MAKE-UP CONCENTRATE STREAM
R_2 - ROTOMETER - DILUTE STREAM FLOW
PG
M
PG
IN
IN
OUT
OUT
V-1
V-2
INSTRUMENT PANEL
PRESSURE LINES
WASTE
PRODUCT
CONCENTRATE STREAM
CV
R_1
PUMP-1
STAGE 2
TWO-STAGE STACK
STAGE 1
PRV
FEED
F
DILUTE STREAM
R_2
CV
PUMP-2

Figure 5. Flow Controls for One Stack

Figure 6 illustrates the flow pattern for multi-stack plants. Feed water to be treated enters the unit from the left under a pressure of at least 30 psig. The water flows through a filter (F) to remove suspended matter and prevent plugging of the membrane stack. This is a replaceable cellulose cartridge type filter using cartridges usually with a rating of not more than 10 microns, a micron being one-thousandth of a millimeter in size. The pressure drop across the filter is normally from three to four pounds. However, as the cartridge becomes clogged, there is a continual increase in the pressure drop across the filter. When the pressure drop reaches about 20 psig, the filter cartridge is replaced. Downstream from the filter is a pressure regulating valve (PRV). This valve automatically increases its opening as the pressure drop through the filter increases, maintaining an approximate constant pressure of about 10 psig downstream. Downstream from the pressure regulating valve, the water branches into two streams. One stream will become the demineralized product (called the dilute), and the other stream will become the concentrated brine blowdown (noted as concentrate in Figure 6).

The water to be demineralized is pumped by booster pump D1, through the ion-losing compartments of stack 1, where approximately 40 per cent of the original mineral content is removed. As is the case in Figure 6, there are four stacks in series. Thus the partially treated water leaving stack 1 still contains 60 per cent of its original mineral content. This water is then pumped successively by booster pumps D2, D3, and D4 through stacks 2, 3, and 4. In each of these stacks about 40 per cent of the remaining mineral content of the water entering the stack is removed, resulting in a final product containing about 13 per cent of the original mineral content. The dilute product is then collected in a storage tank.

While most of the feed water is demineralized as described above, a portion of the feed water is routed through a control valve (CV) and a rotometer (R) into the suction of concentrate pump (C) and thence into the recirculating concentrate system. Pump (C) recirculates a partially concentrated brine water through the ion-gaining compartments of the membrane stack. The ions that are being lost by the treated water are trapped in the ion-gaining compartments and thus picked up by the partially concentrated brine water. To prevent the precipitation of salts in solid form in the stack, the concentration of the brine in the recirculation loop is kept just below the saturation point of the least soluble salt present. The salt concentration in this loop is controlled by a continuous overflow of liquid to waste. The amount of feed water added to the circulation loop is equal to the amount of bleed off of the concentrated brine from the loop. A globe type control valve may be used to regulate the continual bleed-off rate and the setting of control valve (CV) is used to regulate the amount of feed water in this part of the system. The rate of flow of makeup (feed) water to the concentrate loop is registered on rotometer (R). The amount of water that is used in the concentrate loop and disposed to waste varies from a low of approximately 30 per cent of the total feed water entering the system to a maximum of just a little less than 50 per cent of the total feed water. Even with this high amount of water going to waste, the total cost for a large plant (over one million gallons per day) operation will be approximately $0.40 per thousand gallons and that for a smaller plant will approach $1.10. The cost per thousand gallons will generally range between these two figures and will depend not only on the size of the plant, but also upon the content of water to be purified and the degree of purification. Thus, the permeable membrane process can produce demineralized water at a cost competitive with ion exchange or distillation processes.

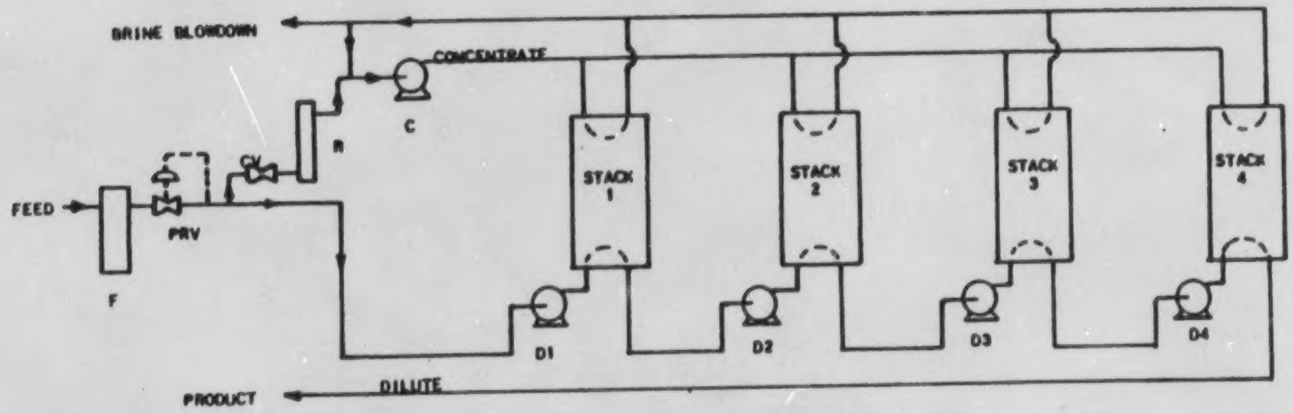

BRINE BLOWDOWN
CONCENTRATE
C
R
CV
FEED
PRV
F
STACK 1
STACK 2
STACK 3
STACK 4
D1
D2
D3
D4
DILUTE
PRODUCT

Figure 6. Schematic Flow Sheet. Four Stage Continuous Unit

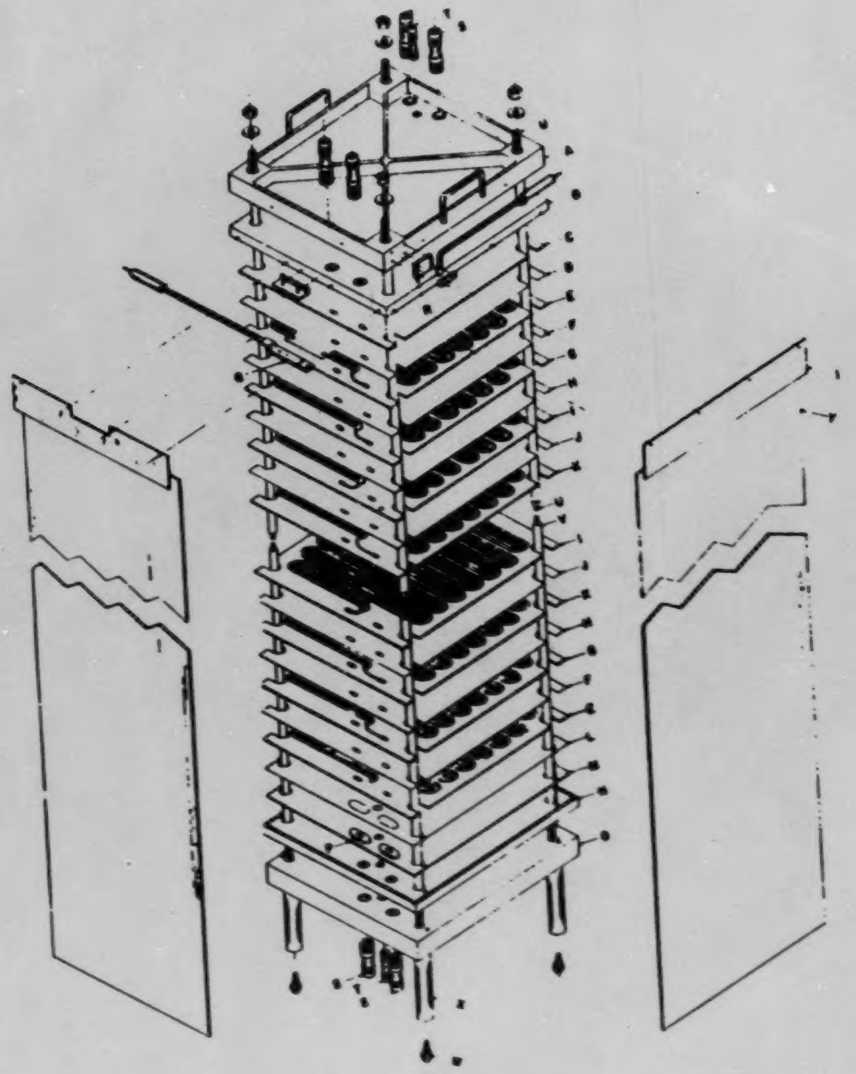
MEMBRANE STACK ASSEMBLY

Certain precautions should be taken in the handling of the permeable membranes during the disassembly and assembly of the stack. These precautions are:

1. Read and follow instructions carefully.
2. The stack is the most important and expensive item of the unit; treat it accordingly.
3. Always keep membranes wet.
4. Do not bend membranes or otherwise physically distort them.
5. Never contact the membranes with anything but feed or processed water or normal drinking water unless advised to do so by the manufacturer. Various chemicals such as detergents, bleaches, and organic solvents can cause permanent damage to the membranes.

There are two basic designs of the permeable membrane stack, with several possible improvements in the future as this is a new process. The first of these two basic designs is the single-stage stack and the second is the two-stage, single stack. The membrane "stack" is so called because it consists of a large number of thin sheets of material stacked on top of each other similar to a deck of cards. This center portion or working part of the stack consists of a repetition of a spacer, an anion membrane, a spacer and a cation membrane. However, as with the single stage, single stack assembly shown in Figure 6, numerous other plates and connections are required to hold the stack together to provide water flow connections and to provide terminals for the required electrical contacts.

Beginning at the top of the stack assembly is the top end plate (A). This steel plate is tapped to receive plastic pipe adapters (S and T) which serve as inlet and outlet connections for the water streams flowing through the stack. There is also a hole in each corner of the plate to accommodate the four tie rods which hold the stack together. As illustrated in Figure 7, holes are cut through all the sheets below the plastic blocks into which the plastic pipe adapters are screwed. These holes in the sheet align with the holes in the block. Two holes, each in opposite corners of the sheet, are used for the flow of water that is treated. Two other holes, each in opposite corners, are used for the concentrated brine that collects the ions. Additional holes are drilled and threaded through the plastic blocks for installation of plastic inserts. These holes are used to vent the gases formed at the anode or cathode and to flush out the compartments adjacent to the anode and cathode plates when the concentration of ions at these electrodes become excessive.



A - TOP END PLATE
B - TOP END BLOCK
C - ANODE GASKET
D - ANODE PLATE
E - ELECTRODE SPACER
F - ELECTRODE ANION MEMBRANE
G - NEUTRAL CONC. SPACER
REPEATING SECTION
H - ANION MEMBRANE
I - DILUTE SPACER
J - CATION MEMBRANE
K - CONC. SPACER
L - CATHODE PLATE
M - CATHODE GASKET
N - BOTTOM END BLOCK
O - BOTTOM END PLATE
P - CATHODE PLATE GASKET
Q - ANODE CLAMP ASSEM.
R - CATHODE CLAMP ASSEM.
S - PLASTIC INSERT ADAPTER - 1"
T - PLASTIC INSERT ADAPTER - ½"
U - TIE ROD
V - INSULATING SLEEVE
W - BALL BEARING CASTER
X - STACK LEG
Y - STACK SIDING

Figure 7. Stack Assembly

Attached to the top plate is the cathode assembly clamp. Below the top end plate is the top end block (B). This is a one-inch thick plastic block which has been tapped in the same place as the top plate. This plastic block is threaded to receive the plastic pipe adapters and thus provides channels through the stack for the fluid flow. This block also has a hole in each corner for the tie rods. Immediately below the plastic block is the anode gasket (C). This plastic gasket is not a spacer and does not have channels cut in it. Its main purpose, like any other gasket, is to assure a proper water seal between the anode and the plastic block.

The anode plate (D) is the next component. It is a thin metal sheet usually of tantalum or titianium and coated with platinum to resist corrosion. Attached to this anode sheet is the anode clamp assembly (Q), the positive pole of the electrical circuit. Below this is the electrode spacer. In some cases this spacer is thicker than the normal spacer and may have no channel cuts. However, for the stack in Figure 7, this spacer is like the other spacers and has channels cut for water flow through it. This spacer, as the name indicates, provides a space between the anode plate and the first permeable membrane sheet. A more detailed discussion of the spacers will follow.

Under the electrode spacer is the electrode anion membrane (F). The anion membrane is a special membrane in that it is thicker than the normal membrane and aids in the prevention of any ion leakage. Adjacent to the electrode anion membrane is a neutral concentration spacer (G). This neutral compartment is formed by being located between two anion membranes. It is called a neutral compartment because there is no net gain or loss of salt. The cations cannot penetrate the membrane on either side of the compartment and are trapped while the anions are continually passing through the compartment on the way to the anode, maintaining the net salt concentration. This concludes the top portion of the stack assembly.

The center portion of the stack assembly is repetitious. Below the neutral concentration spacer is this repeating section consisting of:

1. Anion Membrane (H)
2. Dilute Spacer (I)
3. Cation Membrane (J)
4. Concentrate Spacer (K)

The number of these repeating cells depends upon the design of the stack. One specific design has 150 of these repeating cells.

These permeable membranes look like plastic-coated woven cloth and have two important functions in the operation of the unit. These are:

(1) electrochemical function and (2) structure function. The electrochemical function is the passage of one type of ion in one direction while preventing the passage of ions in the opposite charged ions, also barring the flow of water through the membrane. This transfer of ions must be accomplished with the least possible electrical resistance. Electrochemical properties of ion exchange membranes are measured on small samples and the following properties are normally reported.

1. Electrical resistance or resistivity - ohms/cm^2
2. Perm selectivity - type of ion the membrane will pass
3. Ion exchange capacity
4. Water content

The specific electrical resistivity or conductivity of a membrane is determined by the chemical composition and the method of preparation of the membranes. The electrical "through resistance" or the resistance due to the "drag" of (for example, a positive ion being attracted by the cathode and passing through a negatively charged membrane which has an attraction for the positive ion) a membrane is determined by the specific resistivity and the thickness of that membrane. The ideal membrane would have a thickness of only a few molecules, almost impossible to measure, in order to reduce the "electrical through resistance". However, this would not satisfy the structural requirements of that membrane and would not be practical.

The structural properties of the membrane are important and should include determination of: (1) thickness, (2) burst strength in pounds per square inch, (3) tendency to plastic flow under pressure, (4) deflection under pressure applied perpendicular to the face of the membrane over an unsupported span, (5) ability to withstand shock, (6) fatigue under repeated vibration, and (7) ability to withstand bending and creasing. The new type membrane has a dynel cloth backing. Its weight classification is four ounces, and it has a thickness of 23 mils. These membranes are labeled either cation or anion and can be differentiated from one another by color. The anion is brownish in color and always darker than the cation. The cation membrane is amber colored with a greenish tint. These membranes are capable of operation in units where influent pressures can equal 60 psi or more and where flow velocities can go up to two feet per second. They have burst strength of 140 psi. There is a negligible amount of "bowing" using the four ounce, dynel cloth membrane. "Bowing", if present, would cause changes in velocity flow, turbulence changes and consequent polarization points which might result in precipitation and clogging of the membrane sheet. The dynel cloth backing of the membrane provides the required flexibility of the membrane allowing it to withstand shock and repeated vibration without failure. This type of backing also prevents any tendency for plastic flow. Thus, a membrane has to be designed for both the electrochemical and structural functions with a compromise on the part of each of these to arrive at a practical solution.

Between every two membranes is a spacer made of two thin sheets of plastic material, usually polyethylene or polyvinylchloride. The spacer most frequently encountered consists of two sheets of plastic with the center portion cut to form a flow path. Straps of plastic are run across the flow path to reinforce the plastic barriers forming the flow channel. These straps are the same thickness as the plastic sheet itself and if only one were used, the strap would block the flow of water through the spacer. Therefore, in making the spacer, two plastic sheets are cut with the reinforcing straps in different locations which will allow flow through the spacer. These straps cause an alternating flow of water over one strap and under the next resulting in a rapid stirring or turbulent flow of the water. The evenly distributed turbulence thus created minimizes the chance for local or general polarization caused by stagnant areas of water flow exposed to current. The tortuous path formed by the spacer runs back and forth across the membrane similar to the printed lines on this page. The path, approximately one centimeter wide, traverses the face of the membrane several times and exposed more of the membrane to the water flow which results in more efficient use of the membranes. The length of the path of water flow thus can be 10 to 15 feet on an 18 x 20 inch or 18 x 40 inch membrane.

Each spacer has four manifold holes in it, identical to the manifold holes in the one-inch plastic block, the electrodes and the membranes. If we align all members and spacers in the stack, these manifold holes form four vertical flow headers inside the stack which are under the inlet and outlet pipe adapters that are used to introduce and discharge the water being treated. Since there are two different streams of water flowing through the unit, one a dilute stream and one a concentrate stream, two of the manifold holes are used for flow of one stream and the remaining two holes are used for the other stream. If we cut a notch in the spacer connecting the channel across the spacer with two of the four manifold holes, water will enter the spacer channel from the inlet manifold hole, flow across the membrane through the channel cut in the spacer, and depart through outlet manifold hole. This can then become our dilute flow path or concentrate flow path, depending on its location with respect to the permeable membranes. If the anion membrane is above the spacer and the cation membrane is below the spacer, the flow is that of the dilute or treated water stream. We can make the same connection cut, i. e., connecting the channel cut with two manifold holes, in all of the spacers and by merely turning the spacers over, a connection is made with the remaining two manifold holes. Thus, a dilute space can become a concentrate spacer by turning it over, and vice versa. The concentrate or waste spacer has a cation membrane on top of it and an anion membrane below it and connects the remaining two manifold holes not connected by the dilute spacer.

Just below the last concentrate spacer of the repeating or middle section is the cathode plate (L). This cathode plate is a thin metal sheet usually made of stainless steel or Hastelloy C material. An electrical connection is made between cathode plate and the cathode clamp assembly located at the top of the unit, which connects the negative charge to this plate.

The construction of the rest of the lower portion is similar to that of the top section and contains the cathode gasket (M) bottom end block (N) bottom end plate (O) and the plastic adapters (S and T). One difference is the cathode gasket contains two cathode plate gaskets (P) that aid in insulating and sealing the flow stream manifold holes that pass through the cathode plate.

The stack is held together by four tie rods (U) each being covered with an insulating sleeve (V). As the flow through the stack is through the holes in each sheet of material installed in the unit and not through any piping, the nuts on the tie rod must be tightened sufficiently to compress these sheets and restrict the flow to these holes without leaking between the sheets of material. This explains why the top and bottom end plates are made of steel. The stack stands on the four legs made up on the bottom end of the tie rods. The stack siding is then fastened to the end plates and serves no other purpose than to add to the appearance of the unit and possibly aid in keeping the edges of the sheets dust-free, which is vital in maintaining cleanliness of the membranes when the unit is disassembled.

SUMMARY

Fresh water supply is becoming more of a problem every year, and various methods of removing impurities from salt or brackish water are being used. Salt and mineral impurities are decomposed into ions when placed in a water solution. This split of the compounds results in the same number of positive charges and negative charges being maintained in the water so that the water has no electrical charge itself but can conduct electricity. One of the methods employed is that of the permeable membrane deionizer. This process removes ionized salts and minerals from water by attracting the ions from certain compartments of the unit and trapping them in another compartment.

The source of power used to separate these ions is DC potential, usually obtained from a rectifier. In this type of purification there is no direct chemical reaction as required in most purifying processes or no regeneration process as required in the demineralizer.

The smaller the number of moving parts, the less maintenanance is required on a unit. Various pumps are required with this type of unit, the number depending upon the specific design of the installation. These pumps are utilized to maintain water flow through the "stack" as required. Other pumps are required to pump chemicals into the water at different locations provide efficient operation of the unit. It must be remembered that a stack has to be assembled properly or it will fail to function. Specific types of spacers are required adjacent to the electrodes. The anion and cation membranes which pass only ions, not water, must then be alternated with spacers between each that are connected to alternate parts separating the dilute stream from the concentrate or ion gaining stream.

QUESTIONS

1. What is the size of the largest pore in a permeable membrane?

2. Permeable membranes are impermeable to what substance under normal pressures?

3. Why will a cation membrane repel all anions?

4. Why do anions travel in one direction and cations in the opposite direction in the unit?

5. What gases are released by this unit?

6. Why is the concentrated brine or waste water recirculated through the unit?

7. Which component maintains a constant pressure on the stack as the filter becomes plugged?

8. What are the two basic designs of the permeable membrane stack?

9. What purpose is served by the end plates?

10. Why are the spacers inverted in the middle section of the stack?

11. What are some of the electrical and physical requirements in the design of the permeable membranes?

12. What is the purpose of the straps across the spacers?

SPECIALIZED WATER TREATMENT

OBJECTIVE

To familiarize you with new methods of water treatment.

INTRODUCTION

There is no shortage of water, but there is a shortage of fresh pure water.

If we could remove the salt and alkalinity from brackish water we would have an unlimited source from brackish lakes and the oceans.

In this lesson we will briefly cover three topics:

- REVERSE OSMOSIS
- FREEZING
- ATOMIC DISTILLATION

REVERSE OSMOSIS

Osmosis occurs in every living thing, both plant and animal. All living matter is made up of cells. Cells have water within their cell wall. These cells absorb water through the cell wall.

The small drop of water inside a cell contains salt and other dissolved solids. Fresh water is drawn through the cell wall so as to prevent the water in the cell from becoming too saturated with dissolved solids.

The natural process of water moving through a membrane to an area of greater concentration of dissolved salts is called osmosis.

To demonstrate osmosis we first construct a small rectangular tank. In the middle of the tank we install a membrane that looks like a sheet of thin rubber. We will now add fresh water on one side and salty water on the other. See figure 1.

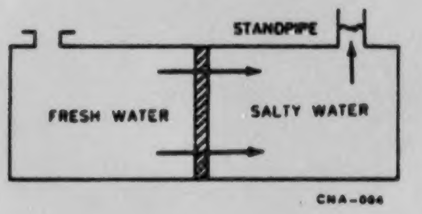


Figure 1. Osmosis

The salty water will draw the fresh water through the membrane. The water in the standpipe will rise.

In reverse osmosis we can use the same setup. This time we will insert a piston in the standpipe so we can apply pressure to the salty water. See figure 2.

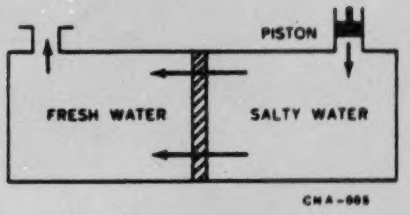


Figure 2. Reverse Osmosis

The pressure applied should be in the range of 100 to 1500 pounds. The amount of pressure depends on the type of membrane used. Water will pass through the membrane leaving the solids behind. There is no chemical reaction involved, it is all mechanical.

Reverse osmosis has many applications such as:

1. Demineralizing sea water.
2. Softening of water.
3. Treatment of boiler feed water.
4. Portable water units.
5. Removing radioactive contamination.
6. Purifying industrial waste water.
7. Tertiary treatment of sewage.

Reverse osmosis is so efficient that some bacteria are filtered out and those that do pass through are easily destroyed by chlorination.

The disadvantages of reverse osmosis are:

1. High initial cost.
2. Membranes coat easily with solids.
3. Turbid water must be filtered.
4. Requires high pressure source.

Further research in better membranes may someday allow widespread use of reverse osmosis. Some cities are using them experimentally now in their water system.

FREEZING

Much study has been done on the freezing process to remove salt from sea water. One successful process is vacuum-freezing vapor-compression. This method is interesting because of its theoretical advantage of conserving energy over other methods of desalting water. It utilizes the vapor created during the vacuum freezing to help produce the salt-free water.

Principles of Vacuum Freezing

You probably have heard that eggs cannot be cooked by boiling on high mountains. This is true because the atmospheric pressure on a high mountain is less than that at sea level. Water will boil and evaporate at this reduced pressure before the temperature is high enough to cook the eggs. When evaporation takes place it removes heat and cools the surface from which it evaporates just as your hands are cooled when water is evaporated from them.

Assume that you have a closed container of sea water. By producing a vacuum in the container the internal pressure will be reduced and the water will give up its heat by vaporizing at its surface. This process is called vacuum vaporization.

Through this process the sea water is cooled until it reaches a point allowing ice, vapor, and liquid to exist at the same time. The ice and vapor formed are salt-free. The liquid remaining, after the ice and vapor is formed, is saturated with salt.

This saturated salt solution is known as a brine solution. Since the brine solution has a lower freezing point than pure water the pressure must be controlled to prevent the brine solution from freezing.

The principle of simultaneous boiling-freezing is simple in principle but is highly sophisticated in its application.

Application of the Vacuum-Freezing Vapor-Compression Process

In the Vacuum-Freezing Vapor-Compression (VFVC) process, sea water is pumped into a vessel evacuated to a pressure at which the sea water can simultaneously exist as ice, vapor, and liquid. When the water enters the pressure evacuated vessel, part of the water flashes to steam and removes heat from the remaining water.

The removal of this heat causes pure ice to form in small crystals at a rate of approximately 7.5 pounds of ice to each pound of steam. About 30 to 40 percent of the sea water is converted to salt-free ice and vapor.

The remaining sea water becomes brine with a 5 to 6 percent salt content. As the ice crystals rise in the vessel the brine is drained off. The ice is then washed to remove any adhering brine and then scraped into a melter. Meanwhile the vapor formed by the flashing of steam is compressed into the melter. In the melter the vapor melts the ice and the ice condenses the vapor. The salt-free product water formed by the melting ice and condensing vapor is delivered to a supply storage system.

The incoming sea water is cooled near its freezing point by heat exchangers in the effluent lines of the cold brine and product water.

ATOMIC DISTILLATION

Distillation is one of the oldest methods known for obtaining fresh water from salt water. All distillation processes involve an input of heat energy to convert a part of the saline water (sea water) to steam, which is then condensed to yield fresh water.

The latest method of desalting sea water by distillation is with the use of an atomic reactor. In order to prevent the atomic reactor from overheating while producing electricity, sea water is used tc keep it cool.

Sea water will flash to steam while cooling the reactor. This steam is collected, condensed, and used as a fresh water supply. This method of producing fresh water from salt water is known as atomic distillation.

QUESTIONS

1. What process is used by plants and trees in obtaining their water?
2. What is the material called that separates the fresh water from the saturated solution?
3. What forms the salt-free water when processing sea water by the vacuum-freezing method?
4. What is used to produce heat for the atomic distillation of water?
5. List three methods of the specialized water treatment.

REFERENCES

1. Reverse Osmosis Systems, Bulletin ROS-101, American Standard, New Brunswick, New Jersey
2. Water Reclamation by Reverse Osmosis, E. Hindon and P. J. Dennett; Water and Sewage Works, February 1969
3. Vacuum-Freezing Vapor-Compression Pamphlet, Colt Industries, Beloit, Wisconsin

DISTILLATION OF WATER

OBJECTIVE

The purpose of this study guide is to develop your understanding of the various methods of distillation. This will include the operation and maintenance of vapor (THERMO) compression units.

INTRODUCTION

Distillation is a process of purifying water by boiling and condensing the vapor produced. Distillation may be used to purify sea water, brackish water from surface and ground sources, and contaminated water. When the content of total dissolved solids in water is very high, and the alkalinity content is low, distillation is frequently the most efficient method of providing usable water. The distillation of water involves the removal of pure water, as steam, from the impurities that it originally contained. The steam is then condensed back into water. Theoretically, there should be no impurities present after the distilling process other than dissolved gases, such as CO_2, which are not removed by distillation, but in practice, the distilled water may contain a few p.p.m. of dissolved solids.

This study guide presents information in two sections. Section A covers methods of distillation, distillation terms, and factors to be considered when determining the need for saline water conversion. Section B covers the operation and maintenance of a vapor compression distillation unit.

The information in section A will be discussed under the following main headings:

- DETERMINING THE NEED FOR SALINE WATER CONVERSION
- METHODS OF DISTILLATION

The information in section B will be discussed under the following main headings:

- OPERATING INSTRUCTIONS
- DESCALING METHODS
- MAINTENANCE INSTRUCTIONS
- TROUBLESHOOTING

SECTION A

DETERMINING THE NEED FOR SALINE WATER CONVERSION

Many coastal areas, islands, and even some inland regions have little or no fresh water, but unlimited supplies of sea water or brackish water are available. When it is necessary to establish and maintain Air Force installations in such areas, the water supply must be derived by converting the saline water into fresh water. Presently known methods of salt water demineralization are quite expensive. Some of the methods include distillation, chemical ion exchange, electric membranes, osmotic processes, solvent extraction of water, and separation by freezing. The oldest and still most practical method is distillation.

The water water produced by distillation is very soft, practically free of dissolved impurities, and contains no bacteria. (It should be chlorinated, however, to provide a measurable chlorine residual protection against entry of bacteria through incompletely covered tanks and plumbing cross sections.) In addition to the unlimited supplies of sea water, tremendous quantities of brackish water are available in tidal areas, marshes, and even inland in salt lakes and underground sources. As supplies of fresh water continue to diminish and the demand for water increases, saline water conversion will become increasingly important.

Objections to Saline Water

Water in bays and harbors may contain between 5,000 and 8,000 parts per million of sodium chloride, while ocean water contains 20,000 to 30,000 parts per million. Water containing excessive amounts of sodium chloride is unfit for drinking, since its taste makes it unpotable and it does not quench thirst. Salt water is corrosive and will damage pumps, valves and pipes through which it is distributed unless special materials are used. Salt water is also unsatisfactory for laundry and washing purposes.

Distillation Terms and/or Nomenclature

The following terms are used when describing or operating a vapor compression or distillation unit.

Blowdown	- The water removed from an evaporator or boiler to prevent the excessive concentration of dissolved solids and the consequent formation of scale.
BTU	- Abbreviation for British Thermal Unit, a measure of work or energy, the amount of heat required to raise the temperature of one pound of water 1^{o}F.
Brackish	- Salty, distasteful, nauseous.
Compression	- Act of forcing a gas or vapor to occupy a smaller volume; this increases its pressure and temperature.
Compressor	- Mechanical device for compressing a gas or vapor.
Condensate	- Product of condensation, distillate.
Condensation	- Act of changing vapor to liquid by removing its latent heat.
Condenser	- Device for removing latent heat from vapor.
Distillation	- Process of changing water into water vapor, separating the water vapor from the water, and changing the water vapor back into water. It is used to separate water from dissolved solids, such as salt.

Distillate	Product of distillation; also called condensate and distilled water.
Effect	One evaporator of a series of connected evaporators of a distillation unit.
Evaporator	Device for changing water to steam and for separating the steam from the water, an effect.
Heat	Energy which causes a body to rise in temperature
Heat Exchanger	Device for transferring heat from a substance at higher temperature to a substance at a lower temperature without physical contact between the two substances.
Latent Heat	Heat involved when a substance changes from one state to another, as water to steam. This heat is not evidenced as a change in temperature.
Oil-Fired	Method of heating water in a distillation equipment with an oilburner, distinct from thermocompression.
Scale	Hard, insoluble layers of certain alkaline minerals deposited on hot metal parts of boilers and evaporators by hard water. Scale reduces heat exchange efficiency.
Steam	Water vapor.
Steam Generator	Device for making steam; an evaporator; a boiler.
Temperature	Degree of hotness or coldness measured on a definite scale.

Thermal Cracking	Method of removing scale from tubes by rapid heating and cooling.
Thermocompression	Method of distilling water by compressing steam.
Vaporize	To change from liquid to vapor, as water to steam, by adding heat.
Water Vapor	Steam; water which has changed to a gaseous state.

METHODS OF DISTILLATION

Distillation is a method of changing water into steam by means of heat and changing the steam back into water by condensation. This process removes impurities and makes even sea water usable for drinking water. The ultimate product resulting from condensation is called distillate. Changing boiling water to steam (vaporization) requires a large amount of heat which does not actually raise the water temperature above 212°F while the water is boiling. To change a pound of water at 212°F to a pound of steam, 972 BTUs are required. This 972 BTU is referred to as latent heat of vaporization. BTU is British Thermal Unit. One BTU is the amount of heat required to raise the temperature of one pound of water one degree, at any temperature. The latent heat remains in the steam which will not condense into a liquid state until the latent heat is removed. A pound of steam at 212°F has to give up 972 BTU of heat to its surroundings before it can change into one pound of water at a temperature of 212°F.

HYDROLOGIC CYCLE. In nature, distillation is carried out on a large scale. Water evaporated from the earth is condensed in the cool atmosphere and is precipitated in the form of rain or snow. Science has benefited considerabily from nature's method of distillation. Man could not live were it not for this distillation. Figure 1 is an illustration of the hydrologic cycle.

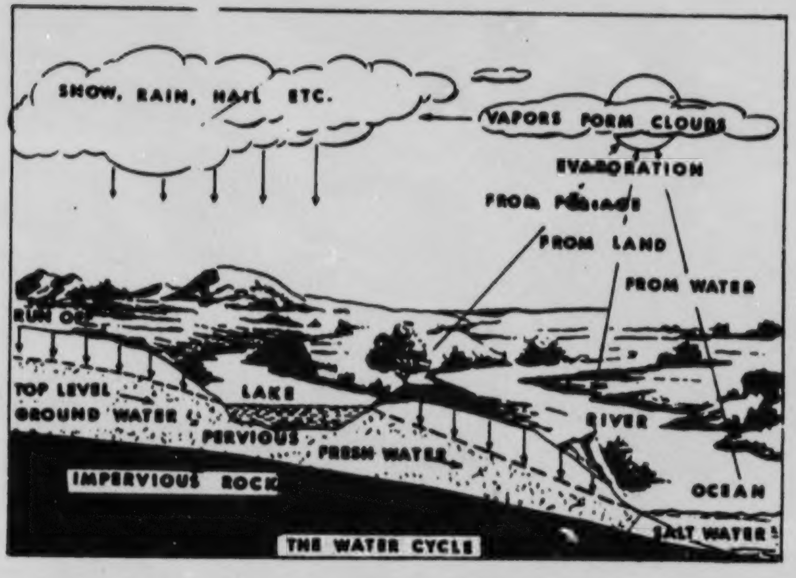

SNOW, RAIN, HAIL ETC.
VAPORS FORM CLOUDS
EVAPORATION
FROM FOLIAGE
FROM LAND
FROM WATER
RUN OFF
TOP LEVEL GROUND WATER
LAKE
PERVIOUS
FRESH WATER
IMPERVIOUS ROCK
RIVER
OCEAN
SALT WATER
THE WATER CYCLE

Figure 1. Hydrologic Cycle

SINGLE STAGE DISTILLATION. The single stage simple distillation unit is illustrated in figure 2. This method is simple but not as efficient as the multiple effect principle which will be discussed later. Single stage units produce about 12 pounds of distilled water per pound of fuel burned.

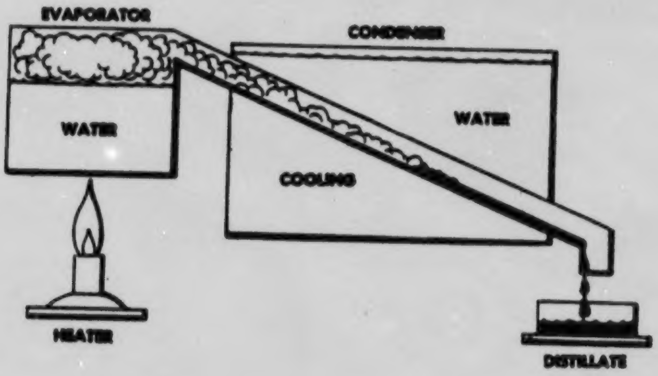

EVAPORATOR
CONDENSER
WATER
WATER
COOLING
HEATER
DISTILLATE

Figure 2. Single Stage Distillation Unit

MULTIPLE EFFECT DISTILLATION. When distilling water in large quantities it is necessary to cool the steam to make it condense quickly. This is done in a condenser where cooling water is circulated around the steam line. The cooling water thus becomes heated. In single effect distillation, the cooling water and the heat it contains are then discharged to waste. The multiple effect process was devised to save the heat given up by the condensed water. In this process, water is heated in an evaporator to produce steam at a given temperature and pressure. This steam is cooled and condensed by using it to heat additional water to form steam at a lower temperature and pressure than the original steam. The steam thus produced may be used a third time to produce additional steam. In this way, nearly all the heat given up by the original steam in condensing to form water is used. Because of increased efficiency, the amount of fuel required per gallon of water produced is approximately one third as much for triple effect distillation as for single effect distillation. Figure 3 illustrates the multiple effect principles of distillation.

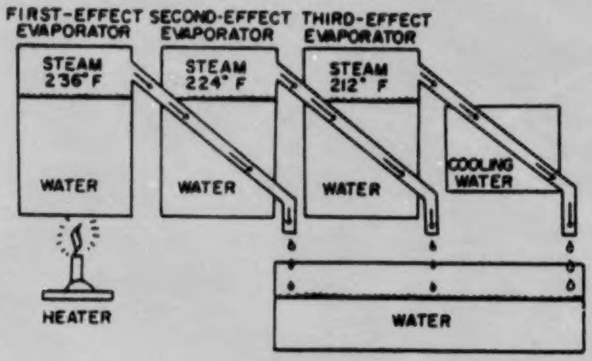

FIRST-EFFECT EVAPORATOR
SECOND-EFFECT EVAPORATOR
THIRD-EFFECT EVAPORATOR
STEAM 236°F
STEAM 224° F
STEAM 212° F
WATER
WATER
WATER
COOLING WATER
HEATER
WATER

Figure 3. Multiple Effect Distillation Unit

EXPEDIENT DISTILLATION. When necessary, expedient stills can be built to produce potable water. All that is needed is a source of heat, a method of forming and collecting steam, and some kind of condenser. The efficiency of such expedients depends on the materials available and the ingenuity of the designer.

Figures 4, 5, and 6, illustrate expedient distillation apparatus. In expedient distillation, sufficient vapor separating space must be provided to prevent carryover of salt with the steam. Care must also be taken to avoid getting salt in the distillate through the expedient means used to condense the steam. To avoid building up steam pressure and endangering personnel, never close off or use a valve in the distillate line.

Figure 4 shows an expedient made of an empty fuel drum or oil barrel, 3/4 and 2" pipe and valves. To operate the unit, fill the drum with water to the level of the overflow pipe and start a fire under the drum. When the water boils the steam passes through the condenser. When starting, keep the feed valve closed until steam appears at the distillate outlet. Then pump water into the cooling water inlet, adjusting the feed valve so the water level remains constant when the water level control valve is barely open. Discharge the remaining cooling water to waste.

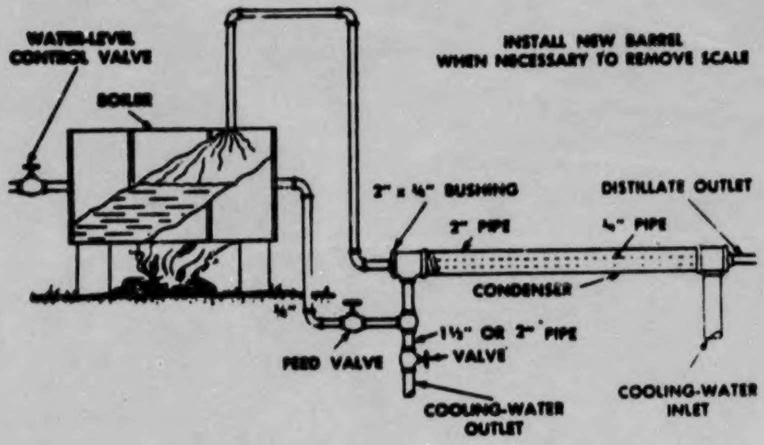

WATER-LEVEL CONTROL VALVE
BOILER
INSTALL NEW BARREL WHEN NECESSARY TO REMOVE SCALE
2" x ¾" BUSHING
DISTILLATE OUTLET
2" PIPE
¾" PIPE
CONDENSER
¾"
1½" OR 2" PIPE
VALVE
FEED VALVE
COOLING-WATER OUTLET
COOLING-WATER INLET

Figure 4. Expedient Distillation Apparatus

Figure 5 shows a method of improving the distillation equipment. The water cooler is constructed exactly like the condenser and serves both to cool the distillate and to heat the feed water. To keep the feed water as hot as possible use only enough water to cause complete condensation.

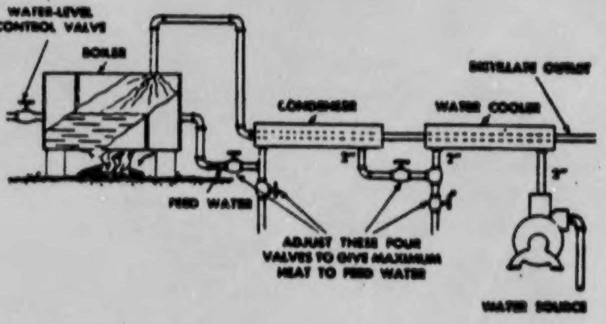

WATER-LEVEL CONTROL VALVE
BOILER
CONDENSER
WATER COOLER
DISTILLATE OUTLET
2"
2"
2"
FEED WATER
ADJUST THESE FOUR VALVES TO GIVE MAXIMUM HEAT TO FEED WATER
WATER SOURCE

Figure 5. Expedient Distillation Apparatus with Distillate Cooler

Figure 6 shows an expedient using a long stretch of pipe as a condenser. Condensation can be made more complete by bending the pipe into curves and immersing it in a pit full of water.

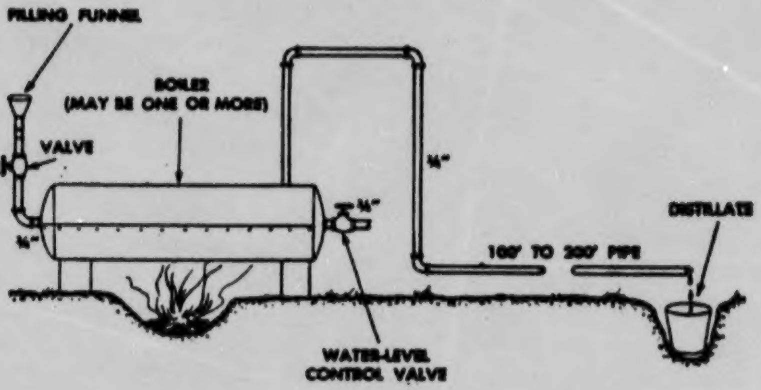

FILLING FUNNEL
BOILER (MAY BE ONE OR MORE)
VALVE
¼"
¼"
¼"
100' TO 200' PIPE
DISTILLATE
WATER-LEVEL CONTROL VALVE

Figure 6. Expedient Distillation Apparatus with Air Cooled Condenser

VAPOR COMPRESSION DISTILLATION. Distillation is a process of vaporizing unpotable water by boiling and then condensing the resulting vapor into a pure distillate. Here is how a unit functions:

Raw water is supplied to the unit by the feed pump. A valve admits the raw water into the heat exchanger in the proper quantity. Within the heat exchanger, a counterflow of feed water to distillate and brine results in a transfer of heat to the feed, economically reclaiming some of the potential heat loss to both the distillate and the blowdown. The heated feed leaving the heat exchanger passes through the vent condenser and enters the evaporator through a spray nozzle above the steam coil. The boiling action (initiated by immersion heaters) in the evaporator causes the raw water to percolate upward around the coil. Steam is released as the raw water contacts the coil surfaces. To prevent the salt concentration in the water from becoming excessive, a portion of the concentrated water which has not been converted to steam is continuously discharged. The brine overflow is extracted from the bottom of the main shell through a downtake pipe projecting vertically inside the shell. A pump, termed the blowdown pump, suctions the brine and discharges it through a vertically mounted heat exchanger (external). A quantity of heat is extracted from the blowdown by the counter flowing feedwater in the exchanger, and then the blowdown is discharged as waste.

The steam generated in the evaporator passes through the mesh separator in the vapor head, where particles of dissolved salt carried by the moisture in the steam are removed and drained back into the feed water in the shell. The dry steam is drawn from the vapor head and compressed by the rotating lobes of the vapor compressor. Compression causes a temperature rise, and the compressed steam is forced into the evaporator steam coils.

The latent heat of the compressed steam is transferred through the tube walls to the boiling water, which results in the compressed steam condensing to distillate. Thus, a continuous flow of vapor is induced between the vapor head and the steam chest, and for each pound of steam condensed in the steam chest, a pound of new vapor rises from the boiling water around the coils. (See figure 7.)

The major source of heat to operate the unit is derived from the continuous re-cycling of the latent heat of steam. The compressor provides a temperature difference between the steam and boiling feed water to effect a transfer of heat and a continuation of the distilling cycle. Auxiliary heat from an electrical immersion heater is required for start-up and for offsetting unavoidable heat losses once the unit is in operation. Heat is lost from the system through radiation, venting of noncondensible gases from the vent condenser, and incomplete recovery of the heat of hot distillate and brine in the heat exchanger.

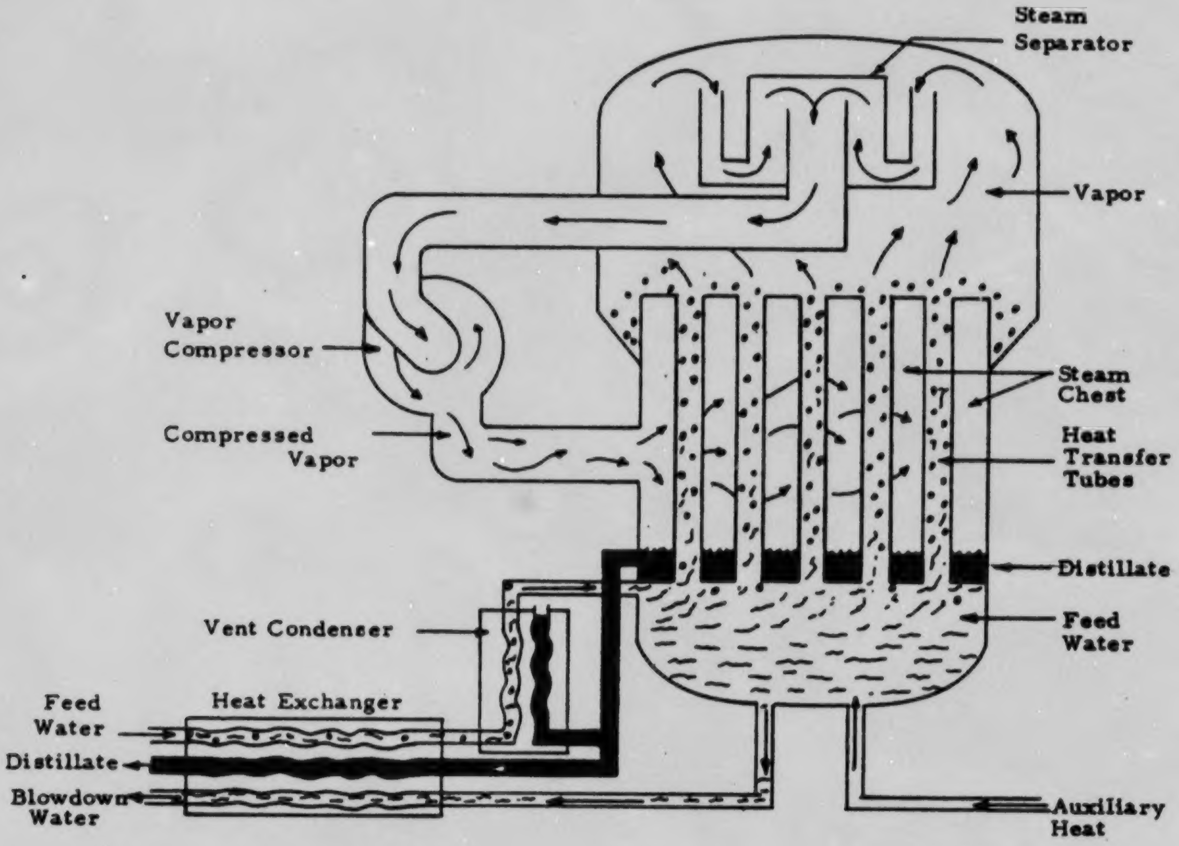

Steam Separator
Vapor
Vapor Compressor
Compressed Vapor
Steam Chest
Heat Transfer Tubes
Distillate
Feed Water
Vent Condenser
Heat Exchanger
Feed Water
Distillate
Blowdown Water
Auxiliary Heat

Figure 7. Vapor Compression Evaporator

Auxiliary heat for the initial vaporization of feed water and for make-up of heat losses during operation is supplied by an electric heater installed in the bottom of the evaporator. The heater heats the cold feed water in the evaporator to its boiling point and the resulting steam is further heated by compression to start the distilling cycle. During operation of the unit, the heater is turned on and off by the evaporator pressure switch operating intermittently to maintain a compressor positive suction pressure.

A fractional amount of distillate is piped from the distillate pump discharge to the suction side of the vapor compressor, to the compressor flushing line, and to the superheater. It serves to lower the operating temperature of the compressor, to seal the compressor rotor clearances and to increase the life of the compressor by flushing off scale deposits. Distillate is also increased by lowering the compressed steam temperature to approximately the saturation temperature corresponding to the steam pressure in order that condensation will occur more readily in the steam chest of the evaporator. The amount of distillate passed to the compressor suction is limited by an orifice nozzle in the flushing line.

Water around the coils is maintained at a boiling temperature by transfer of heat from the compressed vapor condensing on the inner tube surfaces. The distillate flows into the hotwell from which it is then removed by the distillate pumpt. To prevent accumulation of noncondensible gases within the steam coil, these gases are vented to atmosphere through a vent condenser unit. This is a small external heat exchanger which serves to condense steam entrained with the noncondensible gases. The entering feed water circulates a small coil which provides the condensing surface for the steam. Heat is also extracted from the noncondensibles before expulsion.

Concentrated brine is constantly removed from the evaporator during operation through an overflow tube extending upwards into the central downtake. Removal of the brine is necessary to minimize scale formation and to maintain proper water level in the evaporator. The brine is removed by the blowdown pump.

Because the bulk of the heat required to continue the distilling process comes from recycling heat from compressed steam inside the evaporating coils to the boiling water around the coils, the ratio of distilled water output to energy input in the vapor compression type distillation unit is greater than in any other type of distilling equipment.

Continuous recirculation of boiling water inside the evaporator is a feature of this design. The blowdown pump suctions from the bottom of the shell and pumps brine to two points. These are the spray nozzle and blowdown discharge. The spray nozzle is also used for the makeup feed water.

LONG TUBE VERTICAL (LTV) DISTILLATION. Long tube vertical evaporators are more commonly used by chemical companies for the purpose of concentrating of liquors, such as sulfite waste from the pulp industry.

The design of LTV represents one of the cheapest forms of heat transfer per dollar and unit of energy required for operation per dollar.

The use of an LTV evaporator designed for desalting sea water was first suggested by W. L. Badger of Ann Arbor, Michigan, in 1955. In 1957 an LTV pilot plant of 2,000 gallons per day capacity was erected and extensively tested. This plant was located at Wrightsville Beach, North Carolina. The experimental work was under the direction of the Office of Saline Water and W. L. Badger Associates.

The test work resulted in the design of a 12-effect evaporator saline water conversion process which was selected for the first demonstration plant on March 2, 1959, as one of the most promising of the presently known processes for the large-scale economical conversion of sea water to fresh water.

SOLAR DISTILLATION. At the present time much attention is being paid to the development of distillation methods in which the sun serves as a heat source. Shallow troughs of saline water covered with transparent plastic or glass are explosed to the sun. Water vapor rises from the trough and condenses on the cover which is set at a sloping angle. The condensed water droplets converge and flow down the sloping cover to a container. A great area of water surface is needed to produce a sizeable water supply. This solar distillation might eventually prove to be very cheap and efficient, but is not yet developed sufficiently for practical use.

NUCLEAR DISTILLATION. Atomic energy commission scientists believe that in the near future, waste heat from nuclear power plants will be the cheapest way to make fresh water. A nuclear reactor with turbo generators floating off shore could supply enough electricity for a city of five million people and one billion gallons of fresh water a day besides.

SUMMARY OF SECTION A

In order to quickly follow and understand any written material pertaining to the methods of distillation, you must familiarize yourself with a group of new terms.

There are many coastal areas that have a shortage of fresh water and even some of the metropolitan areas will be experiencing water shortages in the future. Since there is an abundance of sea water it becomes necessary to devise a means of making this water acceptable for domestic use. Distillation is a process for making sea water potable.

There are many methods of distillation presently being used, and several more distillation methods are in the developmental stage. Nature's own distillation method is known as the hydrologic cycle. The single stage distillation method is relatively simple but not practical for large scale use. The multiple effect distillation method is more economical than the single stage method.

The distillation process presently most adaptable and efficient for Air Force use is the vapor compression method. Like the multiple effect process, the vapor compression process also conserves the heat given up by the condensing steam. However, it does this in a single stage, with the result that the unit is smaller and more compact. The effect is achieved by the mechanical compression of the steam.

QUESTION ON SECTION A

1. Define British Thermal Unit (BTU).
2. Explain the meaning of the latent heat of vaporization.
3. What is vapor?
4. What is distilled water?
5. Explain the difference between heat and temperature.
6. What is nature's method of distillation?

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7. In the single stage method of distillation how much distilled water is produced per pound of fuel burned?

8. What unit is used to cool the steam so that it will condense quickly?

9. In the vapor compression distillation system, what supplies raw water to the unit?

10. What is the source of auxiliary heat for the initial vaporization of feed water?

SECTION B

OPERATION AND MAINTENANCE OF THE MECO, MODEL PEE10K DISTILLATION UNIT

INTRODUCTION

The information in this study guide pertains to the MECO, Model PEE10K Distillation Unit. This unit is available in the classroom and is shown in figure 8.

Operating Instructions

The MECO unit is electrical powered. It has two heaters called immersion heaters (No. 11 in figure 8). These heaters turn the raw water into steam. The steam is condensed back into distilled water.

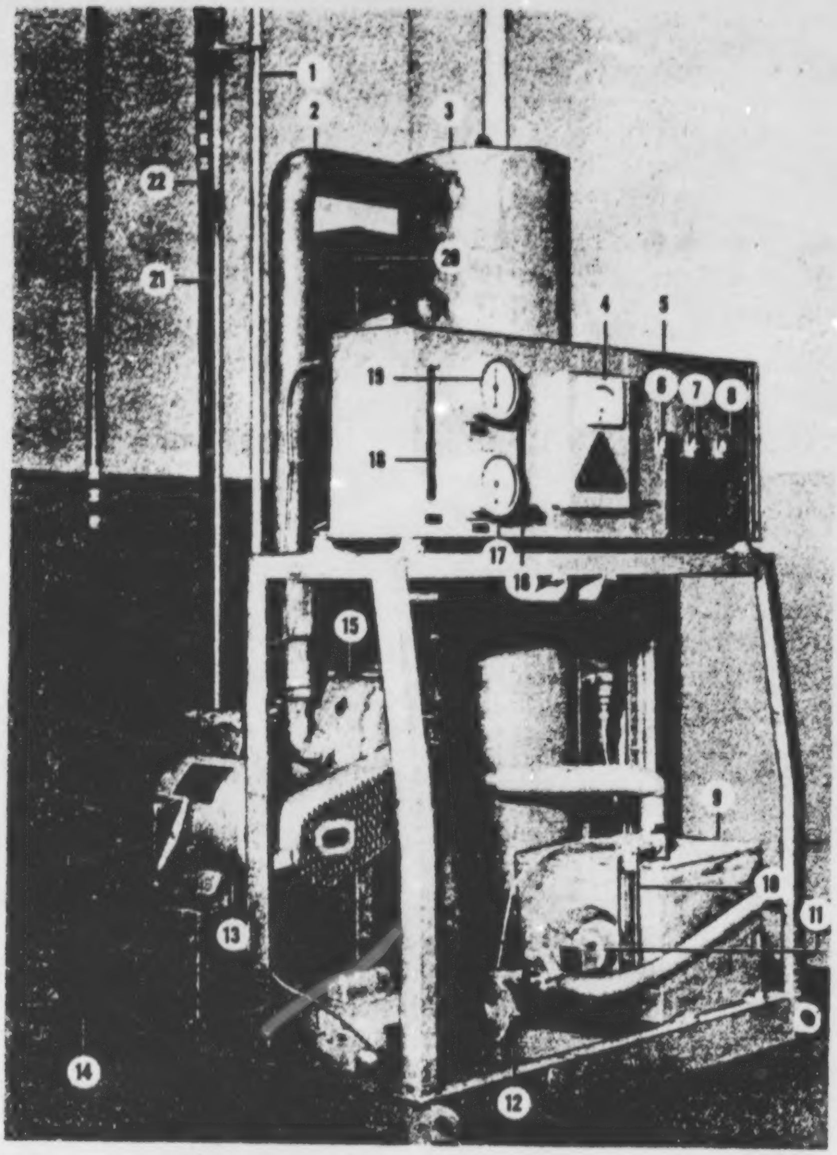
Controls on this unit are electrical. Once raw water is pumped to this unit the automatic controls take over. There are some manual valves that are opened for blowdown and for sample testing. Once these are adjusted for operation the unit will continue to produce excellent distilled water.

The unit is started by pushing the start button (No. 6 in figure 8). The pumps will start, valves will open, the heaters will come on and a conductivitiy meter will indicate the quality of the newly produced distilled water.

Distilled water can be produced at ten gallons per hour from this unit. Nearly all raw water contains scale forming minerals and so after making distilled water for several days or weeks the evaporator will scale up. The first indication of a scale buildup is a gradual rise in discharge pressure. Normal discharge pressure is 3.6 p.s.i.g. Maximum allowable pressure is 6 p.s.i.g. When the pressure reaches 5.2 p.s.i.g., the manufacturer recommends stopping the unit and cleaning the scale as the cake formed will be easier to remove.

Descaling Methods

Two chemical methods of removing scale have been suggested by the manufacturer. One method is to dissolve nitercake (sodium bisulphate) in



1 FEED WATER LINE
2 VAPOR COMPRESSOR SUCTION LINE
3 EVAPORATOR
4 CONDUCTIVITY INSTRUMENT
5 CONTROL PANEL
6 START PUSHBUTTON
7 STOP PUSHBUTTON
8 SELECTOR SWITCH
9 IMMERSION HEATER TANK
10 GAGE GLASS
11 IMMERSION HEATER
12 DISTILLATE PUMP
13 VAPOR COMPRESSOR MOTOR
14 BLOWDOWN PUMP MOTOR
15 VAPOR COMPRESSOR
16 BLOWDOWN FLOW INDICATOR
17 VAPOR COMPRESSOR DISCHARGE PRESSURE GAGE
18 DISTILLATE FLOW INDICATOR
19 VAPOR COMPRESSOR SUCTION PRESSURE GAGE
20 HEAT EXCHANGER
21 BLOWDOWN DISCHARGE LINE
22 DISTILLATE DISCHARGE LINE

Figure 8. Vapor Compression Distilling Unit

water and pour it in the acid injection tank. Nitercake forms an acid when dissolved in water.

Nitercake is effective in removing some types of scale especially that found in sea water. A normal amount of nitercake for cleaning would be 10 to 14 pounds.

A second recommended method is to use muriatic acid (hydrochloric acid). This acid is a very effective descaler when the scale is composed of carbonates.

If scale has become so hard that acid will not remove it, then scale can be drilled and scraped from the tubes; however, there is always the danger of ruining the evaporator tubes.

MAINTENANCE INSTRUCTIONS

Evaporator

Evaporators are built in several arrangements. Most are of the standard type which is usually suitable for industrial use. It is a vertical tube, natural circulation evaporator of medium tube length, with solution to be evaporated inside the tubes. The calandria, or steam chest, which contains the heat transfer surface (tubes) has a large central downtake. All welded joints are accessible for repair at any time. Modern welding techniques are used to assure proper bonding of the various alloys used in fabrication of evaporators for different services. The circulated or percolated solution falls into the downtake. The vapor passes through a separator and out of the evaporator dome. At least one sight glass is usually provided so that this separator action can be observed and both the extent of chemical cleaning, and degree of percolation seen. A bottom head provides access to the bottom tube sheet. The necessary connections for distilled water outlet, feed inlet, blowdown outlet, gauge (level) glasses, etc., are provided. Insulation is of the highest quality, of a type undamaged by moisture (usually Fiberglas), and permanently fastened in a manner which enables servicing the evaporator without damaging the insulation. Tubes are expanded into the tube sheets, and vary in diameter and wall thickness according to evaporator size and purpose and/or customer's specifications.

Various types of separators are used, depending on the service. The separator in the Model PEE10K consists of a 4" thick metal demister pad. The pad is made of interwoven monel wire with approximately .006" diameter. This type of separator is highly effective with a very small pressure drop.

Proper distillate removal is assured by continuous operation of a distillate pump. A distillate gauge glass indicates whether distillate is being properly removed.

Most solutions, when evaporated, give off air and other noncondensible gases. These gases pass around into the steam chest and are vented off through a bottom vent and a top vent. Usually, about 2/3 of the gases will come out of the bottom vent. The top and bottom vents are piped to a common line leading to an automatic thermostatic type vent valve.

A large drain or blow-off valve is provided in the bottom head of the evaporator. It is preferable to open this valve daily, for a few seconds, to blow-down the evaporator.

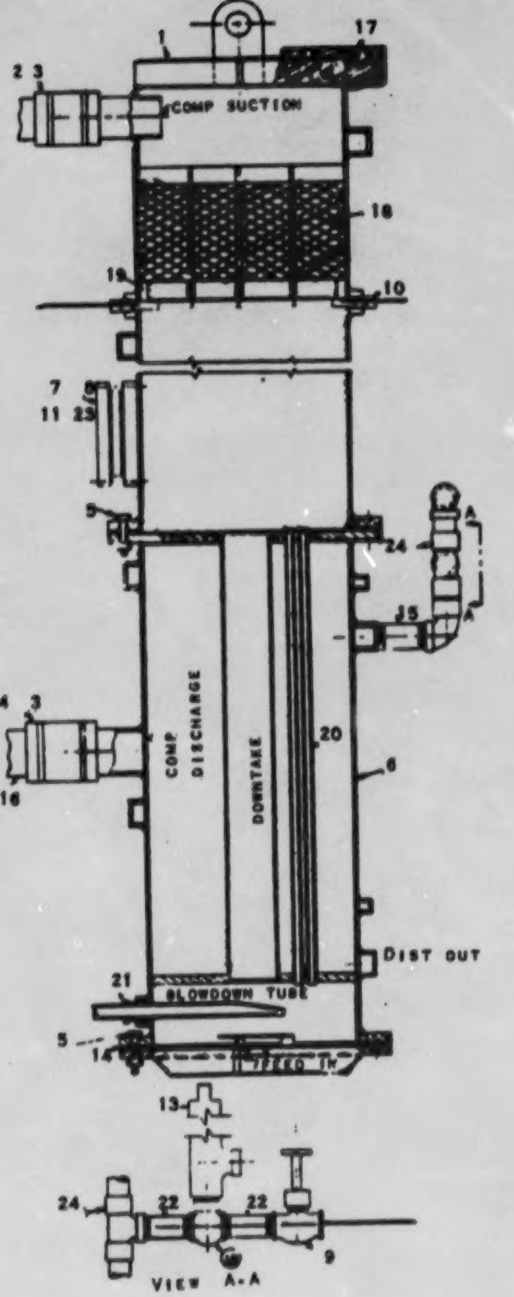
Vapor pipe connections are usually made by special synthetic rubber steam hose. This isolates compressor vibration, and prevents expansion and contraction stresses between compressor and evaporator. Stainless steel hose clamps are provided.

Level gauge glasses using standard size glass are provided. A level is employed that will provide a good percolation with minimum hydrostatic heat loss with average sea water.

A safety valve is provided on the steam chest, usually set at ten pounds p.w.i.g.

Feed is introduced in a manner providing good mixture with the "circulated" solution and good distribution throughout the bottom head. It is most important that feed cannot "short-circuit", or pass into blowdown outlet directly.

Blowdown is removed from a location assuring removal of the most concentrated solution.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COMP DISCHARGE
DOWNTAKE
DIST OUT
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BLOWDOWN TUBE
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FEED TK
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9
VIEW A-A

BILL OF MATERIAL

ITEM	NAME OF PART	PART NO.	QTY.
25	EVAPORATOR COMPLETE	130691	
24	TEE	250372	1
23	GASKET	130702	2
22	NIPPLE	250355	2
21	BLD'N TUBE	130700	1
20	EVAPORATOR TUBES	130699	187
19	LOWER DEMISTER GRID	130698	1
18	DEMISTER	130697	1
17	INSULATION	130696	1
16	NIPPLE	250354	1
15	NIPPLE	250353	1
14	GASKET	130698	2
13	SAFETY VALVE	250352	1
12	TEE	250351	1
11	SIGHT GLASS	130703	1
10	DEMISTER RETAINER	130694	2
9	GATE VALVE	250350	1
8	SIGHT GLASS RETAINER	130701	1
7	CAPSCREWS (NOT SHOWN)	350205	6
6	CALANDRIA COMPLETE	130693	1
5	BOLT AND NUT	350203	22
4	STEAM HOSE	250347	1
3	HOSE CLAMP	250346	6
2	STEAM HOSE	250345	2
1	DOME COMPLETE	130692	1

Figure 9. Evaporator

A chemical cleaning vent valve is provided to allow elimination of the noncondensible gases which are usually generated rapidly upon introduction of acid feed to the evaporator. This valve also permits blowing off the excess steam caused by the heat of the chemical reaction.

Tubes can be removed by several means, the most successful of which is usually the following: Screw an "easy-out", or pipe tap, into the bottom end of the tube (after top and bottom heads of the evaporator have been removed). Secure a steel rod about 6" longer than the tube and lower it into the tube until it rests on the easy-out. Peen the top of the tube end around the rod so as to eliminate the bell shape of the tube end. Use a heavy hammer, and strike the rod with solid blows. This will drive the tube out and free of the tube sheet. Pull the tube down to the floor and bend it close to the tube sheet. By alternately pulling and bending (or cutting), it can be removed. Always follow this procedure, as other methods usually result in blwing the tube between the tube sheets.

Periodic inspection, perhaps every six months, should be made of the evaporator tubes, bottom and top head interior, bypass valve seat, separator, etc., so that corrections to chemical cleaning procedure and/or preventive maintenance can be accomplished.

See figure 9 for details of the evaporator unit.

Vapor Compressor

The vapor compressor is a rotary positive displacement unit with many unique features. It utilizes an exclusive three-lobe rotor design with all parts machined to aircraft tolerances. Timing gears are specially forged, heat treated and crown shaved with a maximum permissible backlash tolerance of .0015". Flush ground double row ball bearings control limited clearances. End plates are specially drilled to allow free flow of lubrication between bearings and seals. Specially designed oil slingers and retainers assure proper oil lubrication.

Two impellers rotate on two shafts in a housing. Each impeller has two lobes (involute type) and is keyed and pressed on its shaft; Steam is displaced by the rotation of the two impellers in opposite directions. The endplates close off the ends of the housing. Note cross-section drawing for further details of construction.

The impellers must have very close clearances between each other and the cylinder and the endpaltes in order to obtain high volumetric efficiency. This merely necessitates care in properly adjusting the machine, and securing all locking devices so that it will remain in proper adjustment.

Main points of wear are bearings, oil seals, shaft seals and timing gears. These parts may be renewed whenever required.

Compressor V-Belt Drive Arrangement

The sheaves are of the taper lock type, i.e., the bushing in the sheave is split and is a tapered fit in the sheave. This facilitates ease of removal and assembly.

The compressor V-belts should not be unduly tight, as this will overload the bearings in the front end of the compressor, as well as on the driver motor. Do not stretch belts to install them. Loosen the motor mounting bolts and slide the motor towards the compressor so that the belts can be put on without forcing. Jacking screws against the motor allow it to be moved away from the compressor to tighten the V-belt drive until the belts are fairly snug. Be certain the sheaves are properly aligned when tightening the belts. To do this, it will be necessary to have the belt guard removed.

Sheaves and belts must be kept free of oil and water so that excess belt slippage cannot occur.

Do not use belt dressing on these belts. If they begin to slip, clean with a cloth dampened in gasoline and tighten the drive slightly.

Electrical Control Equipment

The unfailing continuity of service of electric motor controlling equipment can only be assured by a planned program of periodic inspection and maintenance.

Keep the control equipment free from accumulation of dirt, dust, grease, or oil, both inside and outside. Clean the operating mechanism and the contacts with a dry cloth, or with a vacuum cleaner. (Use of compressed air is generally not recommended, as it may blow metallic dust with such force as to pierce insulation or cause short circuits between conductors or other electrical parts.) Small and delicate mechanical parts may be cleaned with a small stiff bristle brush and a nonflammable cleaning fluid.

Moving parts should be kept clean and should move freely, without binding or sticking, in their normal operating travel. Bearing surfaces that require lubrication should receive a few drops of light machine oil taking care to wipe off any excess oil. In general, bearings which operate on a shaft or pin require lubrication. Knife edge bearings, plunger type armatures, etc., which may become "gummed up" due to collection of dust and evaporation of the oil, should not be lubricated.

Contacts are the basic functional parts of all motor control, and proper operation depends upon their being maintained in good operating condition. When a contactor closes, it does so with a considerable force and there is always a certain amount of rebound of the individual contact. During the rebound, small arcs are formed and, if the contacts should close again at exactly the same point, there would be a possibility of their becoming welded. However, since the armature of the contactor has moved in farther during the time of the rebound, the contacts come together at a different point and so do not weld under normal operating conditions. The arcing, however, both on closing and opening, causes the burning away of the contact material and forms small pits in the contact surface. With the self-cleaning contact construction, this arcing is carried by the contact tips, leaving the heel of the contacts clean to assure maximum efficiency for carrying the operating current.

Copper contacts should be inspected regularly and should be filed or dressed when necessary. Any projection which extend beyond the contact surface should be filed off. If the contacts become badly pitted at the heel or contact surface, they should be filed down so that a clean contact surface is provided. Heavy coatings of copper oxide, caused by the equipment being our of service for a long period of time or by excessive heating, can be removed with a fine file. Welding of copper contacts sometimes occurs - it is usually due to low line voltage. It can also be caused by operating a starter from start to stop too rapidly, or by low spring pressure due to the springs becoming annealed or burned, or because the contact tips have been allowed to wear down beyond their normal wear allowance.

Carbon contacts are used where it is essential that a contactor must always open when it is deenergized and not under any circumstances weld closed. Such contacts are generally used on very essential applications where serious damage may result if a contactor should fail to open.

Silver contacts are used on heavy duty applications where the contactor is to be closed for a long period of time with infrequent operation. Silver contacts rarely require filing and should not be filed or dressed unless sharp projections , caused by heavy arcing, extend beyond the contact surface.

Loose connections between the contact and the contact post or lever will cause heating, which will lead to rapid oxidation of the contacts. Excessive vibration may cause the contacts to vibrate, giving the effect of weak spring pressure and shorten contact life.

High voltage on the holding coils of controllers and relays will cause excessive slam, which will eventually damage the laminations that the magnet faces and otherwise damage the controller.

The magnetic gap of a.c. magnets must always close properly or coil burnout may result. Failure of the magnetic gap to close may be due to low voltage, excessive spring pressure, binding or sticking of the armature.

Damp and corrosive atmospheres may cause damage to the insulation and/or the mechanical parts. Excessive ambient temperature may cause damage also.

TROUBLESHOOTING

SYMPTOM	CAUSE	REMEDY
High compressor suction pressure (above 1/2 p.s.i.) or evaporator relief valve discharges	Failure of pressure switch to break circuit to electric heater on pressure rise	Check for broken, bent or dirty contacts in pressure switch or for short circuit to heater
	Auxiliary heater rate greater than necessary	Adjust pressure regulator switch

SYMPTON	CAUSE	REMEDY
	Faulty pressure gauge	Check and repair or replace
Low compressor suction pressure (below 1/2 p.s.i.)	Failure of pressure switch to close circuit to electric heater on pressure drop below 1/2 p.s.i.	Check for broken, dirty, or bent contacts in pressure switch or for broken or disconnected leads
	Burned out heater	Check operation of heater and replace as required
	Blowdown rate is too high	Adjust blowdown control valve
	Faulty pressure gauge	Check and repair or replace
High compressor discharge	Scaled tubes in evaporator and/or heat exchanger	Clean unit pressure is 5 p.s.i. higher than compressor suction pressure
	Improper venting	Check for obstructed vent orifice
	Accumulation of distillate in evaporator steam chest	Check for obstructions or closed valves in the distillate line
	Low feed water level in the evaporator	Check feed water supply
	Faulty pressure gauge	Check and repair or replace

SYMPTOM	CAUSE	REMEDY
High compressor differential pressure	Scaled tubes in evaporator or heat exchanger	Clean the unit when differential pressure across the compressor reaches 5 p.s.i.
	Accumulated distillate in steam chest	Check for obstruction or closed valves in the distillate piping
	Improper venting	Check for obstructed vent orifice
High compressor differential pressure	Low feed water level in the evaporator	Check feed water supply and orifice in feed line
	Faulty pressure gauge	Check and repair or replace
Failure to hold constant water level	Faulty liquid level controller	Check solenoid valve seat or faulty operation of controller
	Failure of feed water supply	Check source
Foaming	High concentration of impurities in evaporation	Increase blowdown discharge
Excessive bearing or gear wear in compressor	Improper lubrication	Check oil level

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SYMPTOM	CAUSE	REMEDY
Impure distillate	Leak evaporator	Check for tube or shell leaks and repair or replace as needed
	Foaming	Increase blowdown
	Leaky vent condenser	Check for tube leaks and repair or replace as needed
	Leak in heat exchanger	Check for tube leaks and repair or replace as needed
Oil leaks in compressor	Worn out or damaged seals	Replace compressor
Entire system cuts out	Differential pressure too high	See symptom #4
Entire system cuts out	Level in evaporator too high or too low	See symptom #5

RECORDS. It is recommended that complete records be kept by operating personnel as an aid in determining faulty or improper operation. The following data should be tabulated after each start, before each shutdown, and once during each change of operating personnel:

1. Date and time unit started.
2. Date and time unit shut down.
3. Total hours of operation.
4. Total hours of operation since last start.

5. Suction pressure of compressor.
6. Discharge pressure of compressor.
7. Feed rate.
8. Distillate salinity.
9. Electrical power consumed.
10. Maintenance performed.
11. Lubricating oil level checked.
12. Lubricating oil in compressor changed.

Since there is no standard form for recording data, local forms must be produced.

Maintenance of the distillation unit will be facilitated and improper performance more easily noticed, if the operator will keep a daily record of some items. Some suggested records are listed in the chart.

DATE		DISTILLATE FLOW RATE GPM	BLOWDOWN FLOW RATE GPM	COMPRESSOR SUCTION PRESSURE	COMPRESSOR DISCHARGE PRESSURE	LUBRICATION PERFORMED AS PER PAGE D-1

SUMMARY OF SECTION B

Before operating the distillation unit it should first be inspected for serviceability. When starting, stopping or operating the unit it is important that the correct procedure be used.

Scale can be removed by chemical means or by mechanical methods.

As in any equipment of this nature, it is important that the parts receive the proper lubrication and maintenance to insure long life and efficient operation.

It is important to understand the operation of the unit so that troubles which arise can quickly be remedied.

A log should be kept to maintain a record of operating, time, discrepancies, maintenance due and maintenance performed.

The vapor compression unit is balanced so that it will reach a stable operating condition.

QUESTIONS

1. For starting the distillation unit the selector switch is placed in what position?
2. What should the flow rate be on the blowdown motor when properly adjusted?
3. The normal operating water level in the evaporator is how many inches above the top of skid?
4. The unit should be descaled when the discharge pressure reaches what value?
5. What proptective clothing should be worn when working around acid?
6. What type oil is used in the compressor gear section?
7. What type compressor is used in the distillation unit?

8. What is the corrective action for slipping "V" belts?

9. How are projections removed from copper contacts in the electrical equipment?

10. Explain what is meant by balancing vapor compression unit.

11. What protective measures are used during freezing weather with portable vapor compression distillation units?

12. What are the two chemicals used in chemical scale removal?

13. What p.s.i. is the safety valve set at on the steam chest?

14. What type evaporator is on the distillation unit?

15. List five causes for a high compressor discharge pressure.

16. What is the cause for foaming in the distillation unit?

17. What type form is used for recording the running time of the distillation unit?

REFERENCES

1. AFM 85-13, Maintenance and Operation of Water Plants and Systems

2. Aqua-Chem Inc., Waukesha, Wisconsin, Annual Report 1963.

3. Utilities Manual 3 & 2, Bureau of Naval Personnel, Navy Training Course, NAVPERS 10656-D.

FIELD WATER TREATMENT EQUIPMENT
(ERDLATOR)

OBJECTIVE

The purpose of this study guide is to assist you in learning about the 600-GPH field water purification unit.

INTRODUCTION

The water point is established only after determining that the quantity and quality of the water is satisfactory, and the site is well located for access, security, drainage, and bivouac. The development of a field water supply, using the 600-GPH trailer mounted Erdlator as the main purification unit, will be discussed under the following topics:

- GENERAL DISCRIPTION OF EQUIPMENT
- BASIC INSTRUCTION ON SETTING UP EQUIPMENT
- OPERATION

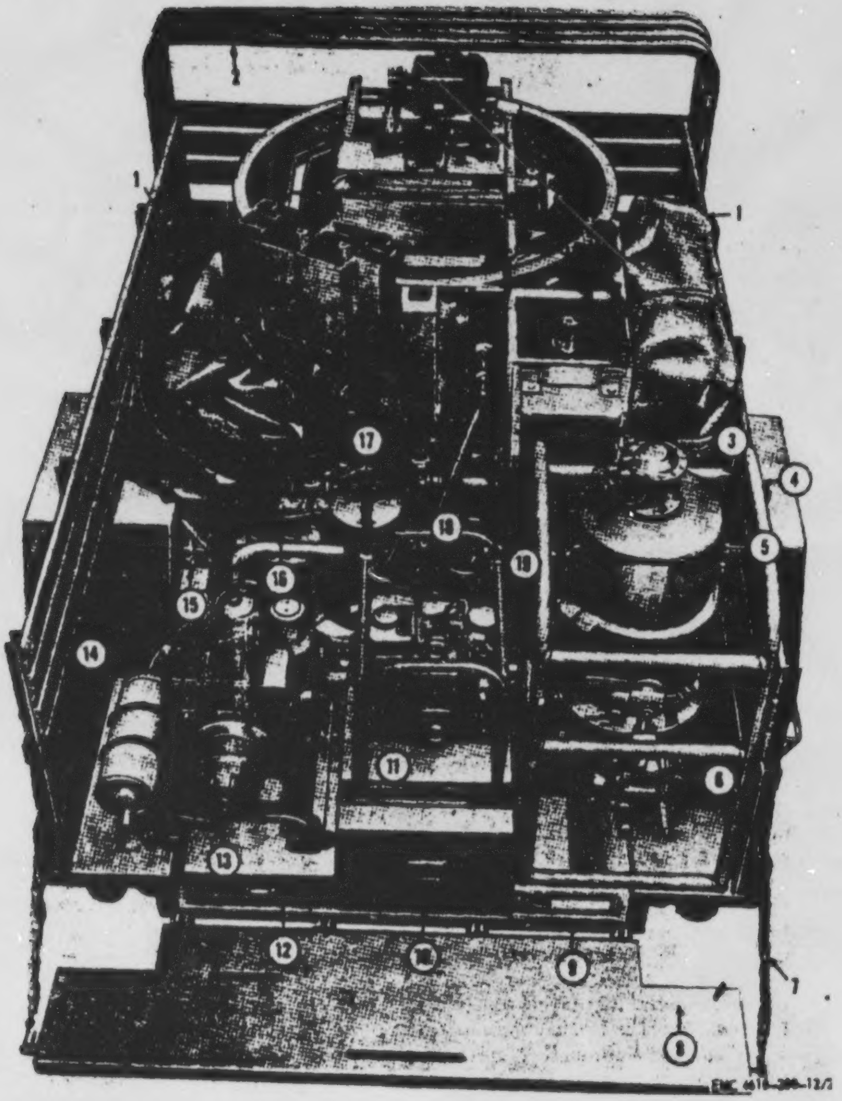
This study guide does not cover all the information on this subject; therefore, research of the references at the end of this study guide is highly recommended.

GENERAL DESCRIPTION

The 600-gallon-per-hour (GPH) water purification unit, see figure 1, is furnished in a special purpose cargo body, mounted on a 2-1/2 ton, 2-wheel trailer. The Erdlator assembly, diatomite filter, filter pump, chemical feed equipment, with necessary piping and valves and the electrical controls, are mounted in the cargo body. These components are designed to be operated with or without the trailer body.

The supporting equipment includes a 3 KW gasoline engine-driven generator set, a gasoline engine-driven pump, a portable electric driven pump, and two 500-gallon collapsible water storage tanks (with ground covers). There is also a supply of hoses, fittings, water testing equipment, and necessary chemicals. The chemicals are ferric chloride, pulverized limestone, calcium hypochlorite, activated carbon, and diatomaceous earth (DE).

NOTE: All units use the same chemicals.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EMC 4610-200-12/1

1. Collapsible fabric tank, 500 gal (2 rqr)
2. Roof bows
3. Air release valve
4. Filter tubular frame
5. Filter
6. Flow controller valve
7. Trailer tailgate chain
8. Trailer tailgate
9. Tool box
10. Chemical box
11. Distribution pump
12. Accessory box
13. Generator
14. Trailer body rack
15. Tank staves
16. Raw water pump with canvas cover
17. Pail tiedown strap and metal cover
18. Rubber pails
19. Filter pump

Figure 1. Water Purification Set Loaded in Trailer

BASIC INSTRUCTIONS FOR SETTING UP EQUIPMENT

When the site location has been determined the unit is then set up for operation.

The unit may be left on the trailer or removed. If the unit is to be left on the trailer, the trailer must set on firm level ground and be leveled. This will be determined by the number of personnel and the length of time the unit is to remain at this location. Remember no matter how the unit is set up it must be level. The equipment is given a thorough inspection for damaged parts and to determine if all the necessary equipment is available and in proper operating condition.

The auxiliary components are removed and set up. They must be set on firm, level ground. The storage tanks must be placed on the proper ground cloth, or on another type of platform. They should not come in direct contact with the ground. When this is completed you will then be ready to operate the unit.

NOTE: See TM 5-4610-202-12, Water Purification Unit (Trailor Mounted) and TM 5-700 Field Water Supply for full details. These manuals should accompany the units.

OPERATION

It is essential that the operator knows how to perform every operation of which the unit is capable. The following paragraphs give instructions on starting and stopping the unit, and on the basic operation of the unit. Since nearly every job presents a different problem, the operator may have to vary the given procedure to fit the individual job.

Chemical Requirements

The following chemicals are required in the treatment and filtration processes:

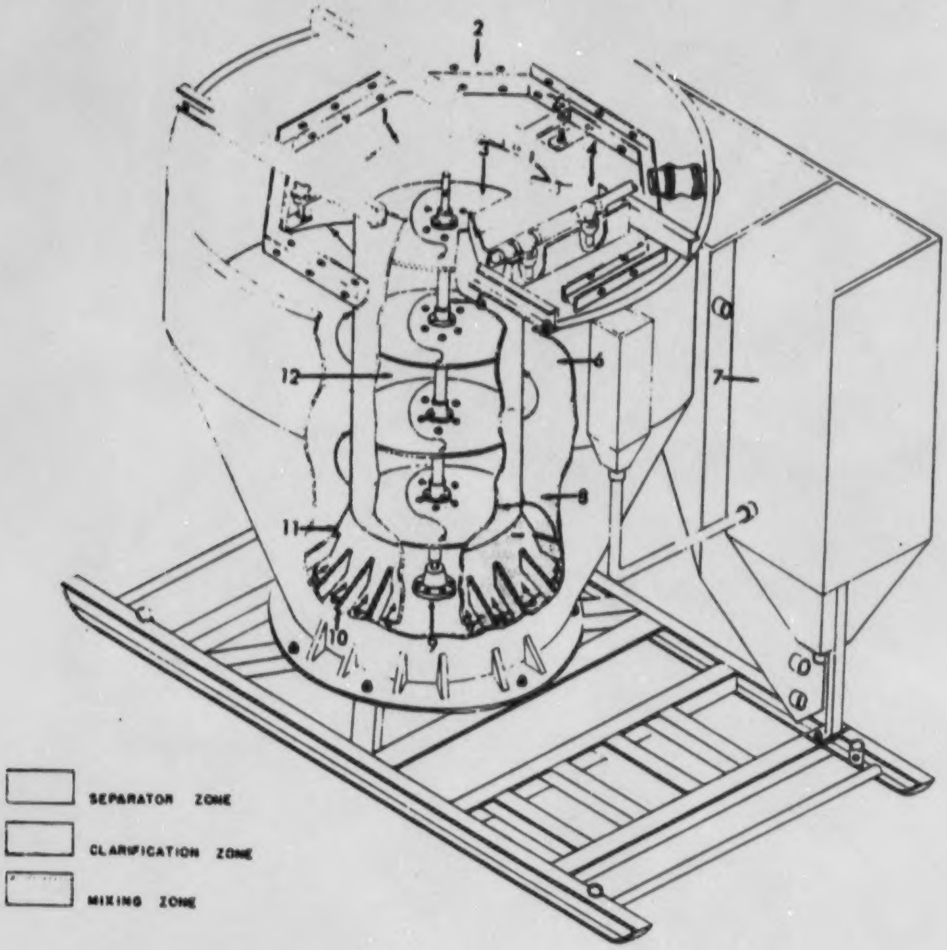
1. Ferric chloride as a coagulant.
2. Calcium hypochlorite as a disinfectant.
3. Pulverized limestone as a coagulant aid.
4. Diatomaceous earth as a filter aid.
5. Activated carbon as an adsorber to control objectionable tastes and odors.

The chemicals are mixed proportionally with water to be treated in accordance with an established base charge. The base charge is the concentration of mixture of solution expressed as the amount of chemicals in a measured quantity of water prepared for the chemical feeder.

Water Treatment Process

The water treatment process reduces the dissolved organic and suspended matter of raw water to a minimum and produces coagulated water suitable for application to the diatomite filter.

ERDLATOR TANK. (See fig. 2). Raw water is pumped from its source by the raw water pump through the aspirator nozzles to the influent launder; from there it overflows into the downcomer or mixing zone.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SEPARATOR ZONE
CLARIFICATION ZONE
MIXING ZONE

1. Downcomer tube
2. Effluent launder
3. Circular disk (4 rqr)
4. Influent launder
5. Agitator shaft
6. Separator zone
7. Sludge concentrator tank
8. Clarification zone
9. Bearing support
10. Baffle
11. Baffle ring
12. Mixing zone

Figure 2. Cross Section of Erdlator

The chemicals, a coagulant (ferric chloride), a coagulant aid (pulverized limestone), a disinfecting agent for pre-chlorination (calcium hypochlorite solution), and, when necessary, an adsorber for objectionable taste or odors (activated carbon) are added in the mixing zone.

As the liquid descends through the mixing zone it is mixed by the agitator. The flow is deflected by a series of shallow baffles in the bottom of the Erdlator tank and directed in a counter-rotating direction into the outer compartment or clarification zone.

Clear water is collected at the water surface in the effluent launder which acts as a double edged weir. The effluent launder is manually adjusted by the leveling rods to permit leveling and skimming of the water surface. The clear water is then discharged to the wet well tank.

The wet well tank provides limited storage of coagulated water and serves as a sump for the filter pump.

An overflow pipe in the wet well tank permits operation of the Erdlator at rated capacity when the filter is stopped. A switch, operated by a float in the wet well, activates an alarm bell and a red signal light when the float valve is open. This allows additional raw water to enter the system whenever the amount of water in the wet well falls below a preset level.

CHEMICAL SOLUTION FEEDERS. The chemical solution feeders pump ferric chloride and calcium hypochlorite solution into the downcomer or mixing zone. The pump discharge rate is adjustable but delivers a fixed constant rate of feed with each pump stroke at any one setting.

CHEMICAL SLURRY FEEDER (LIMESTONE COMPARTMENT). The chemical slurry feeder limestone compartment supplies pulverized limestone (coagulant aid) to the mixing zone of the Erdlator tank.

The limestone slurry is kept in suspension by introducing air at the bottom of the tank.

The feeder operates on a dilution principle whereby 65% of the initial charge of slurry is fed during a one (1) hour period; therefore, the feeder requires recharging with dry chemical every hour. The limestone compartment remains full of liquid slurry but becomes more diluted during the hour until it is recharged.

FILTERING PROCESS. The filtering process further reduces suspended matter by use of DE (diatomaceous earth) filter aid. The filtering process consists of precoating, filtering, and backwash.

Precoating. Before the water can be filtered, it is necessary to precoat the filter element with DE. DE slurry is added to the coagulated water line through the precoat funnel and valve. The coagulated water is pumped from the wet well tank through the filter. The water is recirculated until it appears clear when viewed through the filter window. The valves are then repositioned for the filter run.

Filtering. Filtering removes the remaining suspended matter and organisms from coagulated water. Diatomite slurry is discharged from the diatomite slurry compartment of the chemical slurry feeder to the coagulated water line at the suction side of the filter pump. When the effluent pressure guage reaches 5 psi, the unit is in need of backwashing. The valves must then be positioned for the backwash run.

Backwashing. When the air release valve is in the backwash position, it allows air in the dome of the filter housing cover to bypass the main air valve. This air depresses the diaphragm in the main valve which opens a valve releasing the air in the dome to atmosphere. The sudden release of air allows the air compressed in the cups in each element to expand and force water back through the element filter cake. This rapid reversal of the water usually removes all the suspended matter from the elements.

Most of the removed suspended matter and the water in the influent section will drain to waste through the filter drain. The filter is then washed to remove remaining matter that settled in the filter. After washing, the filter is ready for precoating. This will be determined by the color of wash water going to waste. The valves are then changed to the precoat position.

> WARNING: The eyes and skin must be kept from coming in contact with the chemicals and solution mix. Be especially careful when opening chemical containers to avoid inhaling chemical powder. NEVER mix calcium hypochlorite and ferric chloride, because it gives off a greenish yellow chlorine gas which is irritating, disagreeable, and has a suffocating odor.

SUMMARY

There are two other field purification Erdlators, the (a) 1500 GPH van truck mounted and the (b) 3000 GPH van truck or skid mounted. They all use electrical power and the same chemicals. The only basic difference is the size of the filter, the hoses, the pumps, and the mounting.

Proper planning is essential to the orderly development of a water point. The site requiring the minimum improvements should be selected. The extent to which a water point is developed varies with time, labor, and material available. Development of a water point, at combat areas, however, is to supply enough potable water to the troops with a minimum of improvements.

QUESTIONS

1. How many sizes of Erdlator units are there?
2. What are they?
3. What type of power do they use?
4. What are the chemicals used?
5. What is the purpose of the baffles at the bottom of the Erdlator tank?
6. What must be done to the filter before it is ready to filter water?
7. How often must the chemical slurry feeder be recharged?
8. What must be done to the filter if you have a power failure?
9. How many KW's is the generator designed for on the 600 GPH Erdlator?
10. What is the purpose of the effluent launder?

REFERENCES

TO 40W4-9-1, Operation and Organizational Maintenance Manual - Water Purification Unit.
TM 5-700, Field Water Supply

420

WORKBOOKS
3ABR56631-IV-1-P1 thru 5-P1

17-5

Technical Training

Environmental Support Specialist

SPECIALIZED WATER TREATMENT PROCESSES

October 1975

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
Department of Civil Engineering Training
Sheppard Air Force Base, Texas

Designed For ATC Course Use

DO NOT USE ON THE JOB

SPECIALIZED WATER TREATMENT PROCESSES

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This supersedes WBs 3ABR56330-IV-1-P1, July 1973; 3ABR56330-IV-2-P1 thru 5-P1, February 1972; 3ABR56330-IV-3-P1, June 1975.
(Copies of the superseded publication may be used until stock is exhausted.)

Dept of Civil Engineering Training
Sheppard AFB, Texas

WB 3ABR56631-IV-1-P1
October 1975

OPERATION OF WATER SOFTENER TRAINER

OBJECTIVE

The objective of this workbook is to provide step-by-step procedures for operating the water softener trainer.

INSTRUCTIONS

Follow the instructions below for operating the water softener trainer. Each item of guidance is important for proper operation and the steps listed should be followed in the order presented.

SAFETY PRECAUTIONS

1. This trainer is designed to teach the flow and physical operation of ion-exchangers during different phases of operation. It is recommended that chemicals NOT be used under classroom conditions. If regeneration is desired, use NaCl only.
2. Never allow water pressure in unit to exceed 20 p.s.i.
3. When changing cycles, the hardwater inlet valve should be opened last and closed first to prevent excess pressure in system.

PREOPERATIONAL CHECKS

NOTE: Check schematic for location of valves and lines.

1. Close all valves.
2. Check pressure regulator for a system pressure of 15 to 20 p.s.i. and adjust if required.
3. If the water level in the ion-exchange tank is more than one inch below the top of the tank, fill and purge air as follows:
    a. Open both backwash valves.
    b. Open hardwater inlet valve just enough to allow water to fill tank but not enough to cause expansion of bed.
    c. When water reaches the distributor in the top of the tank, close the hardwater supply and backwash valves.
4. If water level in the brine tank is lower than 3/4 full, fill to desired level as follows:
    a. Open the service valve, drain line, brine outlet valve, and hardwater inlet valve.

   b. When the 3/4 full level is reached, close ALL valves, starting with the hardwater inlet valve.

5. If the trainer has been shut down for an extended period of time, place it in fast rinse for a short period of time before placing the trainer in the service.

   NOTE: See fast rinse procedures under Operating Sequence in this workbook.

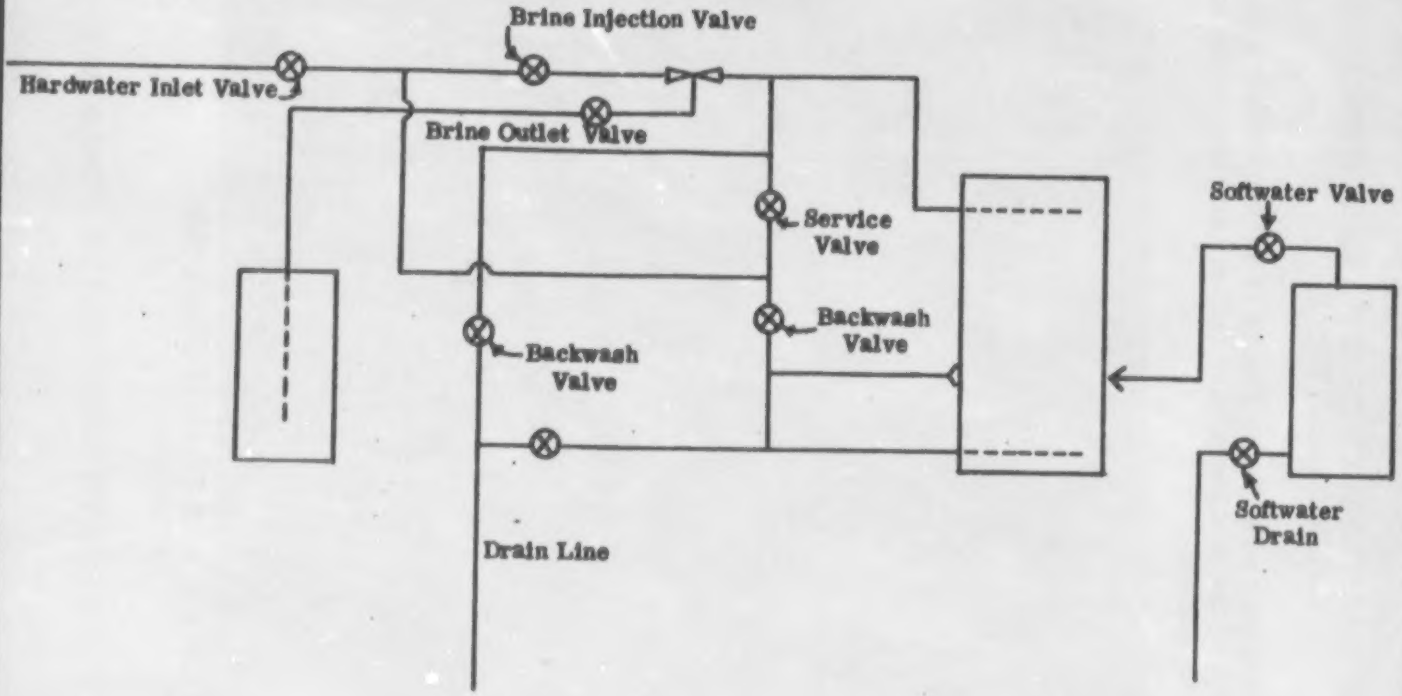
OPERATING SEQUENCE

1. Place the unit in service as follows:
   a. Open service valve, softwater valve, and hardwater inlet valve.
   b. If softwater tank is over 3/4 full, open softwater drain valve enough to prevent overflow from top of tank.
2. Backwash the bed as follows:
   a. Close all valves, starting with the hardwater inlet valve.
   b. Open both backwash valves.
   c. Open the hardwater inlet valve slowly until the bed expands approximately 50 percent.

      CAUTION: A too high backwash rate will cause zeolite to wash off to drain. Backwash for one minute.
   d. Stop backwash by closing all valves, starting with the hardwater inlet valve.
3. Place unit in the Chemical Injection Phase as follows:
   a. Open brine injection valve, drainline valve, and hardwater inlet valve.
   b. Open brine outlet valve. When sufficient chemicals have been drawn into the bed, 1 to 2 inches of water, go to step 4.
4. Slow rinse the bed as follows:
   a. Stop chemical injection, step 3b above, by closing the brine outlet valve. This places the unit in slow rinse.
   b. Stop slow rinse by closing brine injection valve. Leave other valves as they are.
5. Fast rinse the bed as follows:
   a. Following step 4b above, open service valve. This places the unit in fast rinse.
   b. To place the unit in service at the end of fast rinse, open softwater valve and close drain line.

POSTOPERATIONAL CHECKS

1. Check valves and tanks for leaks and cracks.
2. Close all valves except the backwash valve to drain.


Brine Injection Valve
Hardwater Inlet Valve
Brine Outlet Valve
Softwater Valve
Service Valve
Backwash Valve
Backwash Valve
Drain Line
Softwater Drain

SCHEMATIC OF WATER SOFTENER TRAINER

OPERATION AND MAINTENANCE OF THE ELECTRODIALYSIS DEMINERALIZER

OBJECTIVES: To familiarize you with the theory of electrodialysis and to guide you in the operation of the demineralizer trainer and the maintenance of the permeable membrane stack.

THEORY OF PERMEABLE MEMBRANE DEIONIZATION

NOTE: This exercise should familiarize you with the electrochemical function of the membranes and with the formation of the dilute, concentrate, neutral and electrode streams in a permeable membrane stack.

PROCEDURE

1. In figure 1, using a pencil, draw a line showing the direction each ion will be moved by the charges on the anode and cathode.

2. If the ion passes through the membrane, draw the line across the membrane.

3. Where the membrane stops the ion, draw a small circle at the end of the line.

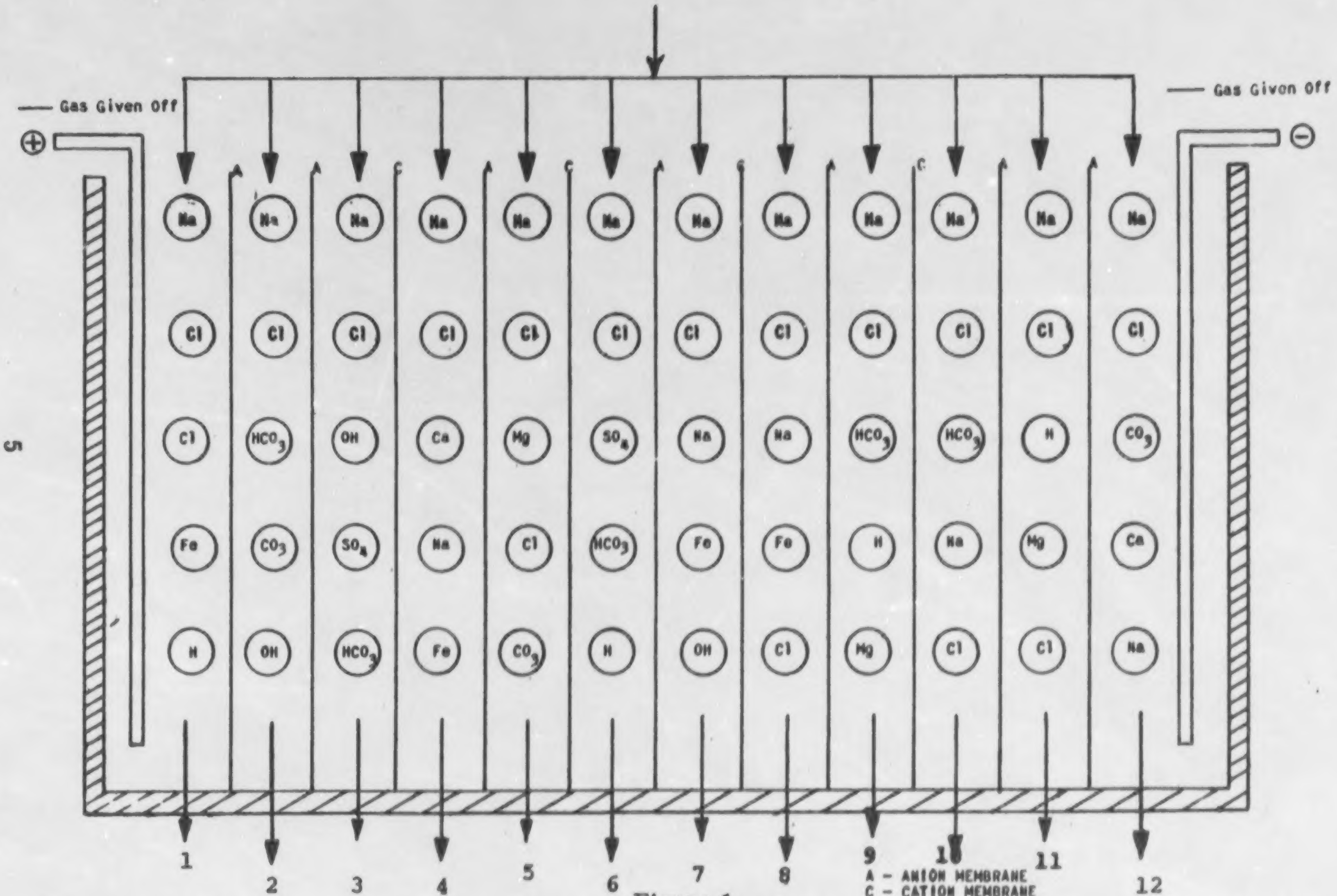
4. Fill in the blanks at the bottom of figure 1, identifying the streams as follows:

D - Dilute stream
C - Concentrate stream
N - Neutral stream
Cath - Cathode stream
An - Anode stream

5. Show the pH change and the gas formed in the electrode streams.

OPERATION OF THE ELECTRODIALYSIS TRAINER

NOTE: Observe safety as listed in the Safety Checklist attached to the side of the rectifier.


Gas Given Off
⊕
Gas Given Off
⊖
Na
Cl
Cl
Fe
H
Na
Cl
HCO3
CO3
OH
Na
Cl
OH
SO4
HCO3
Na
Cl
Ca
Na
Fe
Na
Cl
Mg
Cl
CO3
Na
Cl
SO4
HCO3
H
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Fe
Cl
Na
Cl
HCO3
H
Mg
Na
Cl
HCO3
Na
Cl
Na
Cl
H
Mg
Cl
Na
Cl
CO3
Ca
Na
1
2
3
4
5
6
7
8
9
10
11
12
A - ANION MEMBRANE
C - CATION MEMBRANE

Figure 1.

PREOPERATION PROCEDURES

1. Fill the raw water tank.
2. Open the water supply valve.
3. Check the solution in the acid tank.
4. Inspect the trainer for any damage.
5. Position all switches OFF.
6. Connect the power cord to 110V a.c. outlet.

OPERATION PROCEDURES

1. Start the unit by following the Starting Procedures attached to the side of the rectifier.

2. Record the readings from the following gages and meters. Check the log sheet for correct readings.

   a. Pump discharge pressure ____________
   b. Pressure after filter ____________
   c. Pressure after P.R.V. ____________
   d. Product flow rate ____________
   e. Stage 1 - Volts ____________
      Amperes ____________
   f. Stage 2 - Volts ____________
      Amperes ____________
   g. Temperature of feed water ____________
   h. Conductivity - Feed Cell ____________
      - Product Cell ____________

3. Stop the unit by following the stopping procedures.

Stack Maintenance

NOTE: The following is a step by step procedure for disassembly and assembly of a membrane stack. Read all the following instructions through before attempting any maintenance on a membrane stack.

Precautions

1. Do not bend the membranes or allow them to come in contact with sharp objects.

2. Handle plastic end blocks carefully to prevent breaking or loosening the plastic connectors.

3. The edges of the electrodes are SHARP! Handle them carefully

4. Do not begin stack disassembly until you are sure the rectifier is disconnected from the main power source.

Disassembly

1. Insure that the d.c. rectifier is disconnected at the power source.

2. Remove the stack end plate.

3. Remove the plastic end block. Do not lay the block on the plastic hose connectors.

4. Remove the top electrode gasket and top electrode.

NOTE: Before actual membrane and spacer removal, the operator should wash his hands to prevent bacterial contamination of the membranes.

5. The disassembly can be done either in sections or in pairs.

6. To maintain proper order for reassembly, turn the membranes over when placing them down during disassembly.

NOTE: When disassembling a two stage stack, the procedure listed above will be used for the second stage also.

Assembly Precautions

1. To prevent assembly errors, place a schematic of the stack in a location where it can be referred to constantly during the assembly.

NOTE: Always grease the edges of the electrode for a good seal. Edges Only! Never grease the flow path area.

2. Alternate anion and cation membranes except at the electrodes.

NOTE: The platinized side of the ANODE faces the center of the stack.

3. Check manifold alignment carefully.

4. Do not introduce foreign material to the stack.

Assembly

1. When replacing the membranes, either by pairs or by sections, the operator must turn the membranes over so they will be in the correct position.

2. Carefully line up the membranes and spacers so that the manifold holes form a vertical flow header for the entering streams.

NOTE: When assembling a two stage stack, the above procedures are followed for the second stage.

3. Replace the top electrode section and top end blocks in the reverse order of disassembly.

4. Grease the edges of the electrode with silicone grease.

5. Tighten binding bolts alternately and only enough to stop excessive leaking with the pump on.

REVIEW QUESTIONS

1. The five streams of flow through a membrane stack are:

a. ____________________ b. ____________________

c. ____________________ d. ____________________

e. ____________________

2. To prevent bacterial contamination of the membranes, the operator

should ____.

3. Why must the membranes be kept wet at all times?

____

4. What is the electrochemical function of the membranes?

____

5. Why should the operator turn the membranes over while removing or replacing them?

____

6. List the parts of a stack that form a repeating section.

a. ____________________ b. ____________________

c. ____________________ d. ____________________

SPECIALIZED WATER TREATMENT

OBJECTIVE

Using related information, state the application of the reverse osmosis process of water treatment.

PROCEDURE

With the aid of your study guide and notes, enter the correct answer in the space provided after each question.

1. What is the purpose of reverse osmosis? ____________________
____

2. What type membrane does reverse osmosis use? ______________
____

3. What type process is reverse osmosis? ____________________
____

4. List six advantages of reverse osmosis. ____________________
____

5. List four disadvantages of reverse osmosis. _________________
____

6. What is the pressure range of reverse osmosis? ______________
____

DISTILLATION TERMS

OBJECTIVE

This exercise is designed to aid you in learning the terms used with the Vapor Compression Distillation Unit.

PROCEDURE

1. In the left column a through k are terms used in vapor compression distillation. Match term with proper description in right column.

a. Heat
b. Compressor
c. Latent heat
d. Evaporator
e. Condenser
f. B.t.u.
g. Temperature
h. Distillate
i. Heat exchanger
j. Immersion heater
k. Temperature of compressed steam

_____ 1. Mechanical device for compressing a gas or vapor.

_____ 2. A measure of heat or energy.

_____ 3. Used to transfer heat from a substance at higher temperature to a substance at lower temperature without physical contact between the two substances.

_____ 4. Heat which is not evidenced as a change in temperature.

_____ 5. Degree of hotness or coldness.

_____ 6. Product of distillation.

_____ 7. Device for changing water to steam.

_____ 8. Energy which causes a body to rise in temperature.

_____ 9. Device for removing latent heat from vapor.

_____ 10. 222°F.

_____ 11. To supply heat for starting as well as supply make-up heat.

OPERATING THE MECO WATER DISTILLATION UNIT

OBJECTIVE: To teach you the operating procedures for the distillation unit.

OPERATING INSTRUCTIONS

Pre-Start Procedure

1. Check all lubrication points.

2. Close evaporator and immersion heater drain valves.

3. Fill immersion heater tank with fresh water through fill hole in top of tank. Fill until water shows midway between gauge cocks on tank level gauge.

Starting Procedure

1. Manual Start

    a. Position selector switch to "hand".

    b. Depress start button. This energizes the control circuit, starting the compressor motor, distillate pump, blowdown pump and energizes the immersion heaters.

    c. Position salinity control switch to "on".

    d. When the unit first starts, the compressor draws air from the steam chest and evaporator tubes. This air is compressed around the tubes which can create an excessive pressure differential and collapse the tubes. To prevent this possibility, the vapor bypass valve opens when the pressure on the suction side of the compressor drops below 0 psi. When the unit produces enough steam to bring the suction pressure above 0 psi, the valve closes.

e. When the unit begins distilling, the liquid level in the immersion heater tank will increase; this causes the float valve to open, permitting distillate to flow from the unit. The flow switch is actuated at a flow rate of 7 to 8 g.p.h., energizing the blowdown solenoid valve, permitting the flow of blowdown from the unit. The flow switch is adjusted to actuate at a flow of 8 g.p.h. and 1.5 p.s.i.g. differential across the orifice.

f. The blowdown valve (on the blowdown meter) should be adjusted to give a flow rate of 8 to 11 g.p.h.

g. When the suction pressure reaches 1.0 p.s.i.g, the pressure switch controlling the immersion heaters will then regulate the heat impact to maintain approximately 1.0 p.s.i.g suction pressure.

2. Automatic Start

a. Position selector switch to "Auto".

b. Position salinity control switch to "On".

c. The float switch in the distilled water storage tank will start and stop the unit as required. The unit will operate automatically with no further adjustment necessary, providing the manual blowdown valve has been set to a predetermined flow rate of 8 to 11 g.p.h.

Unit Operation

After the starting procedure has been followed through, the system is maintained in balance by the pressure switch controlling heaters. Any adjustment to this switch should be made slowly and proper time allowed between adjustment for the unit to stabilize itself. The heater pressure switch should open at about 1.1 p.s.i.g, and close at about 0.9 p.s.i.g. Adjust only if necessary.

Check the blowdown meter frequently and maintain flow rate of 8 to 11 g.p.h. For minimum scaling rate, blowdown should be at least 8 g.p.h. Very little added cycle length will result from more blowdown, but in summer blowdown rate may be increased to 12 g.p.h. With cold feed water in winter, it may be necessary to reduce blowdown rate to reduce heat losses, but never operate with less than 5 g.p.h. blowdown since concentration in the evaporator becomes excessive and scaling rate will increase.

The raw water level in the evaporator is maintained at a constant level by means of the feed float valve. A gauge glass attached to the feed float valve provides a means for ascertaining the liquid level in the evaporator. The normal water level in the evaporator when operating is about 15" above the top of the skid. This level should be checked periodically.

The level of water in the immersion heater tank should be checked periodically. The proper water level in the immersion heater tank when operating is 3" above the nut on the lower gauge cock.

The unit is equipped with a thermostatic vent valve which automatically eliminates noncondensable gases (air, CO_2, etc) from the steam chest and prevents excess pressure buildup. Excess venting wastes steam. On the other hand, too little venting raises the discharge pressure. In either case, the electrical load is increased.

Desuperheating water is injected into the steam line at the compressor discharge through a small capillary tubing. This eliminates any super heated steam and provides the delivery of saturated steam to the steam chest.

Every day of operation, the large drain valve in the bottom head of the evaporator should be fully opened for a few seconds. This removes sediment and precipitated scale from the evaporator.

Lubricate and maintain the unit in accordance with instructions contained in this manual.

Clean the blowdown meter as often as necessary to maintain accurate readings. Only a small amount of dirt, marine life, etc., can cause erroneous readings, which may be either too high or too low. The manual blowdown valve may require a slight adjustment from time to time as a result of dirt or small particles of scale lodging between the needle valve and seat.

The immersion heater tank is equipped with a low water level switch, which will automatically shut the entire unit down in the event a low water condition is experienced in the tank. This safety device is tied into the holding coil circuit and will completely deenergize the electric system when actuated. The unit is also equipped with an indicating salinity control which is used in conjunction with an alarm, providing a means to determine an excessive salt content in the distilled water.

When the discharge pressure has gradually increased to 6.0 p.s.i.g., the unit must be stopped and scale removed. For details refer to section on removing scale. Should the discharge pressure rise rapidly and not due to normal operating cycle conditions, look for other source of trouble. It is recommended that cleaning be done when discharge pressure reaches 5.2#, in order that the motor will not be overloaded when acid cleaning. When the unit is clean, the discharge pressure should be about 3.6 p.s.i.g.

Stopping Procedure

1. Manual Stop

   a. Depress "Off" button (red button). Unit will stop automatically.

   b. Close feed shutoff valve in feed supply line.

   c. Drain sea water from evaporator if unit is to remain idle for longer than two days.

2. Automatic Stop

   a. Float switch in the distilled water storage tank normally stops the unit when the tank is full.

   b. If necessary the unit can be stopped by positioning the control switch to "Off".

   CAUTION: Drain all water from unit if it is apt to be exposed to freezing weather conditions.

   c. To drain:

      (1) Evaporator: Open drain valve.

      (2) Immersion Heater Tank: Open drain valve.

      (3) Cooler: Loosen hose connections at inlet and outlet.

      (4) Distillate and Blowdown Pump: Remove drain plug.

      (5) Piping: Break any connection in lines where water is apt to be trapped.

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FLOW PATTERN FOR VAPOR COMPRESSION DISTILLATION UNITS

OBJECTIVE

To develop your understanding of the flow routes through which water passes through the Model PEE-10K, Vapor Compression Distillation Unit.

INSTRUCTIONS

Figure 1 shows a simple piping diagram of a distillation unit; using figure 2 as a guide, line over the connecting piping between the various components to code each of the systems listed below in separate colors.

1. Feed Water
2. Product Steam
3. Steam and Distillate
4. Blowdown
5. Distillate (Product)
6. Starting Heat

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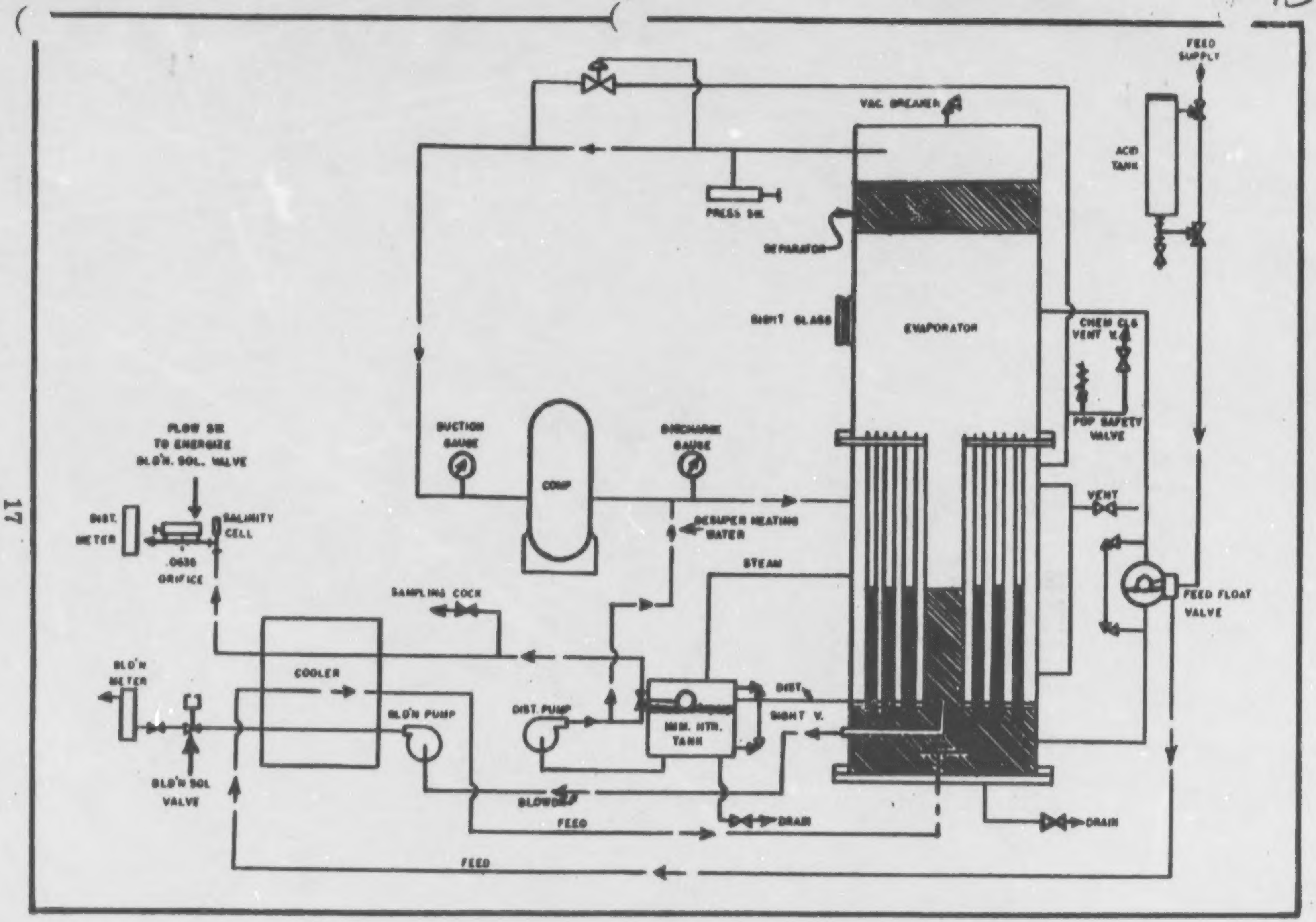
FEED SUPPLY
VAC. BREAKER
ACID TANK
PRESS SW.
SEPARATOR
SIGHT GLASS
EVAPORATOR
CHEM CL& VENT V.
POP SAFETY VALVE
FLOW SW. TO ENERGIZE BLD'N. SOL. VALVE
SUCTION GAUGE
COMP
DISCHARGE GAUGE
VENT
DIST. METER
SALINITY CELL
.0635 ORIFICE
DESUPER HEATING WATER
STEAM
FEED FLOAT VALVE
SAMPLING COCK
COOLER
BLD'N METER
BLD'N PUMP
DIST. PUMP
MIN. HTR. TANK
DIST.
SIGHT V.
BLD'N SOL VALVE
BLOWDOWN
FEED
DRAIN
DRAIN
FEED

Fig. 1 **Distillation Unit, Model PEE-10K**

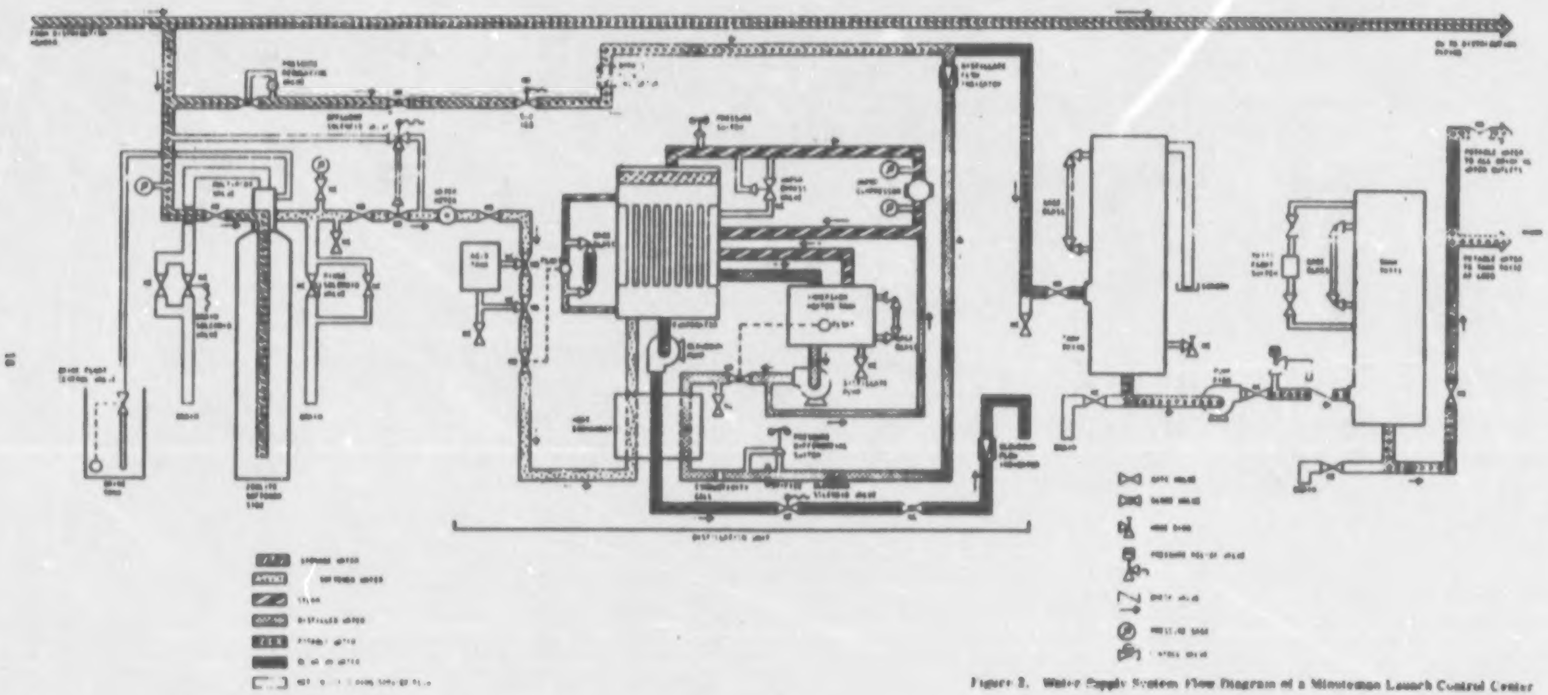

Figure 2. Water Supply System Flow Diagram of a Minuteman Launch Control Center

FIELD WATER PURIFICATION UNIT

OBJECTIVE

The objective of this workbook is to aid you in gaining a better understanding of the purpose and application of the field water purification unit.

PROCEDURES

With the aid of TO 40W4-9-1, your study guide and notes, enter the correct answer in the space provided after each question.

QUESTIONS

1. What is the purpose of the field-type water treatment process?

2. List the sources of water which the 600 GPH field water purification unit can use.

3. What is the purpose of the filtering process?

4. State the operational principles of the 600 GPH field water purification unit.

5. How does the aspirator nozzles aid in the treatment of water?

6. How is the slurry separated from the clear water in the upper cylindrical section of the erdlator tank?

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7. List the five chemicals used with the 600 GPH unit and state their purpose.

8. Where are the waste lines placed during initial set up of the unit and why are they placed there?

9. What is the purpose of continuously feeding diatomaceous earth slurry during the filter run?

10. List the materials that are NOT to be used to clean the equipment surfaces which come in contact with water being treated.

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ALL 566X1 COURSES

17-5

Technical Training

566X1 Environmental Support Career Ladder

SERVICING OF ION EXCHANGERS

October 1975

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
Department of Civil Engineering Training
Sheppard Air Force Base, Texas

Designed For ATC Course Use

DO NOT USE ON THE JOB

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PREFACE

This manual has been written for use in the 566X1, Environmental Support Courses. Its purpose is to bring together in one booklet the step-by-step procedures for regenerating the ion exchangers used in this course.

These procedures have been selected and modified to best fit our classroom conditions. We recommend, that in the event you have to regenerate other ion exchange units, you follow the manufacturer's directions or the directions prescribed by that facility.

TABLE OF CONTENTS

UNIT	PAGE NO
Safety Rules	1
Regeneration of the Chloride Dealkalizer Unit	2
Regeneration of the Sodium Zeolite Unit	4
Regeneration of the Hydrogen Zeolite Unit	6
Regeneration of the Dual Bed Demineralizer	8
Regeneration of the Mixed Bed Demineralizer	11

This supersedes ALL 563X0 COURSES, SERVICING OF ION EXCHANGERS, August 1970. (Copies of superseded publication may be used until the supply is exhausted.)

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SAFETY RULES

The following safety rules should be observed when using acids and alkalies.

1. You must always pour acid into water, never the reverse, when diluting.
2. Always use eye goggles or face shields when pouring acids.
3. Avoid breathing the vapors from acids.
4. Lye water (sodium hydroxide) makes your skin feel slick; avoid splashing it on you.
5. If you get acid or lye water on your hands, wash them gently using lots of water, as either can cause severe burns.
6. If you get a large splash of chemicals on your body, strip off fast and take a shower. There are showers in both chemistry lab rooms.

REGENERATION OF THE CHLORIDE DEALKALIZER UNIT

Preparing the Regenerant

1. Prepare chemicals for regeneration by weighing out 6 pounds of salt and 0.6 pounds of NaOH for each seven inches that the regenerant solution is below the top brine level mark in the tank.

2. Add the chemicals to the brine which is already in the tank.

3. Close valve No. 1.

4. Solo valve is to be in RUN, position No. 3.

5. Open valve No. 4 and valve No. 1 to fill tank to the brine level mark in the tank. Stir the chemicals as the water is being added.

6. Close valve No. 4 when tank is filled to the top brine level mark.

Regenerating the Chloride Dealkalizer

1. Backwash (Step No. 1)

    a. Close valve No. 1 to remove unit from service.

    b. Open drain valve No. 3 to release internal pressure.

    NOTE: This release of pressure is to prevent splattering of water onto the floor.

    c. Place solo valve in WASH, position No. 1.

    d. Control influent (valve No. 1) at 1.6 GPM for 10 minutes or until backwash water is clear and free of suspended material.

    e. Close valve No. 1.

2. Regenerant Injection (Step No. 2)

    a. Place solo valve in REGENERATION, position No. 2. This valve will limit flow to 0.75 GPM.

    b. Open influent valve No. 1 for 18 minutes.

    c. Open valve No. 4 in brine tank line to permit adding brine.

    d. Plug cock valve No. 5 is already set to 0.25 GPM.

    e. Close valve No. 4 in regenerant line after 7 inches of regenerant has been removed. This should take about 18 minutes.

3. Regenerant Slow Rinse (Step No. 3)

   NOTE: Closing of valve No. 4 above started the unit on slow rinse at rate of 0.75 GPM.

   a. Leave solo valve in position No. 2.

   b. Close valve No. 1 after 30 minutes of slow rinse.

4. Final Rinse (Step No. 4)

   a. Set solo valve in RUN, position No. 3.

   b. Open valve No. 3.

   c. Adjust valve No. 1 to 1.6 GPM.

   d. Open valve No. 4 for 10 seconds to flush salt from brine tank pipe.

   e. Close valve No. 3 when water has no salty taste.

5. Service or Run Cycle (Step No. 5).

   a. Solo valve remains in position No. 3.

   b. Check valve No. 2 on service line for OPEN position.

   c. Control the maximum flow at 1.6 GPM by opening valve No. 3 and adjusting flow with valve No. 1.

      NOTE: This flow rate was set correctly during final rinse and will likely need no further adjustment at this time.

      This unit needs to be regenerated when chemical tests indicate that the replaceable anions (CO_3, HCO_3) in the raw water are no longer exchanged for chloride ions.

REGENERATION OF THE SODIUM ZEOLITE UNIT

Preparing Regenerate Solution

NOTE: This step can be omitted if the brine tank contains four or more inches of brine solution. Furthermore, there should be undissolved salt in the bottom of the tank.

1. For each four inches the brine level is below its upper level in the tank, add 15 pounds of salt to the brine tank. For example, if the brine is eight inches low, add 30 pounds of salt.

2. Place solo valve in service position No. 3. Valve No. 1 should be open.

3. Open valve No. 4 and add water up to the "upper brine level," then close.

Regenerating Sodium Zeolite Unit

1. Backwash (Step No. 1)

   a. Close valves No. 1 and No. 2.

   b. Open valve No. 3 momentarily to release pressure in tank and then close.

   c. Place solo valve on BACKWASH, position No. 1.

   d. Control influent by valve No. 1 at 4 GPM for 10 minutes, then close.

2. Regeneration (Step No. 2)

   a. Adjust solo valve for regeneration and slow rinse in position No. 2.

   b. Open valve No. 1. Flow rate is controlled by the solo valve.

   c. Open valve No. 4 to permit addition of salt brine to water going through the resin column. Total brine drawdown is four inches and usual time is about 16 minutes.

   d. Close valve No. 4 when regeneration is completed.

3. Slow Rinse (Step No. 3)

   a. Sixteen minutes after valve No. 4 is closed, begin the slow rinse. Continue slow rinse for 30 minutes.

   b. Close valve No. 1 after the 30 minutes.

4. Final Rinse (Step No. 4)

   a. Place solo valve on service position No. 3.

   b. Fully open valve No. 3.

   c. Open valve No. 1 to give a flow of 2 GPM.

   d. Rinse until salt cannot be tasted in effluent and then close valve No. 3.

5. Service Run (Step No. 5)

   a. Open valve No. 2 on service line.

   b. To adjust to the desired maximum flow:

      (1) Open valve No. 3.

      (2) Using valve No. 1, adjust the desired maximum flow of 6 GPM.

      (3) Then close valve No. 3. This places the ion exchanger back in service.

REGENERATION OF THE HYDROGEN ZEOLITE UNIT

CAUTION: Valve No. 3 should be used to release all internal pressure before moving solo valve off position No. 3.

NOTE: Step No. 2 below is to be omitted in making a "practice run" unless directed otherwise by the instructor.

1. Backwash (Step No. 1)
   a. Close valve No. 1 and No. 2 to remove unit from service.
   b. Open valve No. 3 momentarily to release internal pressure to prevent spilling of water on floor.
   c. Place solo valve on WASH, position No. 1.
   d. Open valve No. 1 to control influent at two gallons per minute (GPM). Let backwash continue for five minutes or until effluent is clear.
   e. Close valve No. 1.
2. Preparing Regenerant Solution (Step No. 2)
   a. Place solo valve on RUN, position No. 3.
   b. Open valve No. 4 to permit water to flow into tank.
   c. Control flow with valve No. 1 up to two gallons per minute.
   d. Add water to within approximately 20 inches from top of tank.
   e. Add 7 1/2 pounds of concentrated sulfuric (1/2 gallon) acid to tank.
   f. Add water until solution is 7.5 inches from top of tank using valve No. 1.
3. Regeneration (Step No. 3)
   a. Place solo valve on REGENERATION, position No. 2.
   b. Open valve No. 1 at 1/2 gallon per minute.
   c. Open valve No. 4 (only for about 5 or 10 seconds for practice during a "practice run").
   d. Close valve No. 4 when solution is two inches from bottom of tank.

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4. Slow Rinse (Step No. 4)

   a. Closing of valve No. 4 in step No. 3 above started unit on slow rinse. Solo valve remains on position No. 2.

   b. Valve No. 1 remains open for 45 minutes (only momentarily for a "practice run.")

   c. Close valve No. 1 after the 45 minutes.

5. Final Rinse (Step No. 5)

   a. Set solo valve on RUN, position No. 3.

   b. Open valve No. 3.

   c. Adjust flow at two gallons per minute, using valve No. 1.

   d. Open valve No. 4 for 10 seconds during rinse to flush lines of acid.

   e. Close valve No. 3 when analysis indicates a complete rinse.

6. Service Run (Step No. 6)

   a. Open valve No. 2 on service line.

   b. Control the flow at desired rate up to two gallons per minute by valve No. 1 and No. 3.

   NOTE: This flow was set correctly during the final rinse and will likely need no further adjustment at this time.

   NOTE: If the unit has not been operated overnight or longer, a short backwash is recommended before putting it back in service.

REGENERATION OF DUAL BED DEMINERALIZER

NOTE: All operations except final rinse and service are conducted separately on each column.

1. Backwash of Cation Unit

   a. Remove unit from service by closing influent valve No. 9.

   b. Place No. 1 solo valve in WASH, position No. 1.

   c. Solo valve No. 2 should remain at RUN, position No. 3.

   d. Open valve No. 9 (influent) and backwash for five minutes at 2 gpm or until effluent is clear. Start this backwash cycle slowly and increase gradually to the prescribed rate. The fast cycle will require placing sampling jar under drain to catch the ion exchange material being discharged.

2. Backwash of Anion Unit

   a. Close influent valve No. 9.

   b. Place No. 1 solo valve in RUN, position No. 3.

   c. Place No. 2 solo valve in WASH, position No. 1.

   d. Open valve No. 9 (influent) and backwash for 10 minutes at 1 gpm or until effluent is clear.

   e. Close valve No. 9.

3. Preparation of Cation Regenerate

   a. Place No. 1 and No. 2 solo valves in slot (No. 3) as part of preparation for adding acid to acid tank.

   b. Open valve No. 9 (influent) and open valve No. 5 to add water to acid tank until water level is about 20 inches from top of acid tank.

   c. Add required amount of H_2SO_4 slowly. This amount is approximately 1 gallon acid with specific gravity of 1.29, or 1/2 gallon acid with specific gravity equal to 1.86.

   d. Open valve No. 5 to add water to tank until level is two inches from top of tank. Then close valves No. 5 and No. 9.

4. Regeneration of Cation Bed
    - a. Place No. 1 solo valve in slot No. 2.
    - b. Place No. 2 solo valve lever in slot No. 3.
    - c. Open valve No. 9 (influent) until flow is 0.75 gpm. Solo valve No. 1 is made to limit flow to 0.75 gpm at common water pressures.
    - d. Open valve No. 5 (acid) to draw it into cation unit. Allow liquid level to drop to two inches from bottom of tank. Suction time is approximately 42 minutes.
    - e. Close valve No. 5 after acid is withdrawn as instructed above.
5. Cation Slow Rinse
    - a. When valve No. 5 was closed above, you placed cation bed in slow rinse. Flow will generally be controlled at 0.75 gpm by No. 2 solo valve.
    - b. Allow the cation unit to rinse for 30 minutes. Then close valve No. 9.
6. Preparation of Anion Regenerant
    - a. In order to prepare regenerant for anion bed, place solo valve No. 1 and solo valve No. 2 in slot No. 3.
    - b. Open influent valve No. 9 and tank valve No. 6 in order to fill tank to within 18 inches from top of tank. Then close valve No. 6.
    - c. Add 6 pounds of flake NaOH to caustic tank stirring as you add the flakes.
    - d. Fill tank with water until level of water is 10 1/2 inches from top of tank by opening valve No. 6.
    - e. Close valve No. 9 and leave valve No. 6 open.
7. Regeneration of Anion Bed
    - a. Place solo valve No. 1 in slot No. 3.
    - b. Place solo valve No. 2 at regeneration slot No. 2.
    - c. Adjust valve No. 9 until water flow is 0.75 gpm. This action allows caustic soda to be sucked up through valve No. 6.
    - d. Close caustic valve No. 6 when solution level is approximately two inches from bottom of tank. Time required is about 17 minutes.

8. Anion Slow Rinse

NOTE: The closing of valve No. 6 above placed the anion bed in slow rinse, and the flow rate is automatically controlled by the solo valve.

a. Rinse for 20 minutes.

b. Then close valve No. 9,

9. Final Rinse - Both Columns

a. Place solo valve No. 1 in slot No. 3.

b. Place solo valve No. 2 in slot No. 3.

c. Open valve No. 12 wide open which will permit effluent to flow into gutter.

d. Set pointer of conductivity meter to 50,000 ohms, and adjust the temperature rheostat to temperature of the effluent. Turn meter switch ON.

e. Adjust valve No. 9 to flow of 2 gpm and allow units to rinse until green light on conductivity meter burns continuously.

f. Open valves No. 5 and No. 6 for about 10 seconds during rinse to flush chemicals out of lines. This will reduce corrosion.

g. Close valve No. 12 when green light comes on.

10. Back to Service - Both Columns in Operation

NOTE: When you closed valve No. 12 above, you placed the demineralizer back to service provided that valve No. 13 is open.

Valve No. 9 remains at present setting of 2 gpm so that this will be the maximum flow. For startup after shutdown overnight, a short backwash is recommended before putting unit into operation.

REGENERATION OF THE MIXED BED DEMINERALIZER

Preoperational Procedures

1. Place all red handle valves in horizontal position.

2. Open main ion exchange water supply valve.

3. Close the decarbonator and automatic pH trainer influent valve.

4. We are going to use the water that comes from either the sodium or hydrogen cation exchanger so place the solo valve of either in service position and open the influent valve. Adjust flow between 3 and 4 gallons per minute.

5. Use the drain valve behind the automatic pH trainer to flush the lines free of iron rust. Open the valve until you have flushed about 5 gallons of water.

6. Open valves E, B, and H, briefly, flow about 2 gallons of water then close these valves.

Normal Operation

1. Open valves E, A, and H.

2. Check water pressure on the gage. It should read between 20 and 30 psi.

3. Check water purity by pressing the ohmmeter button. Any reading above 1 million is good.

To Shutdown Operation

1. Close valves H, A, and E.

2. Close the main ion exchange water supply valve.

3. Shutdown the cation unit you are using and relieve the pressure in the unit.

Regeneration

1. Backwash and separate

All valves closed, (B), (V) valves full open. Open (H) valve until a trickle of water comes out of the drain pipe.

After five minutes of this slow flow rate observe the resin. If there is a slow movement of the resins in an upward surge, the flow rate is fast enough. However, if there is no apparent movement in the resin bed, increase the flow rate by adjusting valve (H). It is very important that the flow rate is not excessive as it will drive the resin bed completely to the top of the column, thereby causing a plug that will not separate. If this occurs, the resin bed will have to be driven down. This is easily accomplished by closing all valves and opening valves (A), (H), and (E). When slug of resins is driven down, proceed with backwash and separate cycle for 15 minutes.

2. Regeneration of the Cation and Anion Resin

Preparing the regeneration solutions - fill a 3-gallon rubber bucket with 2 gallon of softened or demineralized water and stir in 5 pounds of caustic flakes stirring until thoroughly dissolved. One gallon of 30 percent muriatic acid is used full strength for the cation regenerant.

Drawing Up Anion Regenerant

All valves closed, open valves in this order (C) and (C'). Slowly open valve (H) until the pressure gage shows 15-20 pounds. Open valve (K) full. This regenerant cycle should take at least 20 minutes so as to allow contact time with the anion resin. Adjust valve (H) accordingly. Close all valves.

3. Rinsing

All valves closed. Open valves in this order (H), (A), and (K). Continue in this cycle for 20 minutes or until the pH of the drain effluent is approximately 8-9. Close all valves.

4. Regenerating Cation Resin

All valves closed. Place acid draw-up tube in muriatic acid. Open valves in this order: (D'), (D), (K), and (H). Adjust (H) valve so that acid draw-up takes 10-15 minutes. When acid is drawn up, close (D') and (D) valves. Open (B) valve, readjust (H) valve to slightly increase the flow rate. Rinse cation resin in this position for 10 minutes. Close all valves.

5. Air Mixing of the Resins

(1) To drain water level to approximately 4" above resin bed.

All valves closed. Open valves (V) and (E). When water level is reached, close (V) and (E).

(2) Open valves (B), (V), and open valve (J) slowly until agitation of the resin bed starts. A mild agitation is all that is necessary. Observe resin for complete mix. This cycle will take approximately 4 mintues. Close all valves.

NOTE: If resin bed appears too dry and not mixing, properly add water by opening valve (H).

6. Final Rinsing

Fill the tank by backwashing rapidly, open valves (V), (B), and (H), to drive the bed down. Close (V), (B) and (H). Open valves in this order. (A), (H), and (E). Turn on conductivity meter. When minimum conductivity is reached, turn on (F) and close (E). Unit is now in service.

Flow control can be adjusted by valve (H) up to 120 gph or wide open.

NOTE: If unit shows preliminary exhaustion, go through the air mixing cycle. This usually adds about 20 percent more to the run cycle.